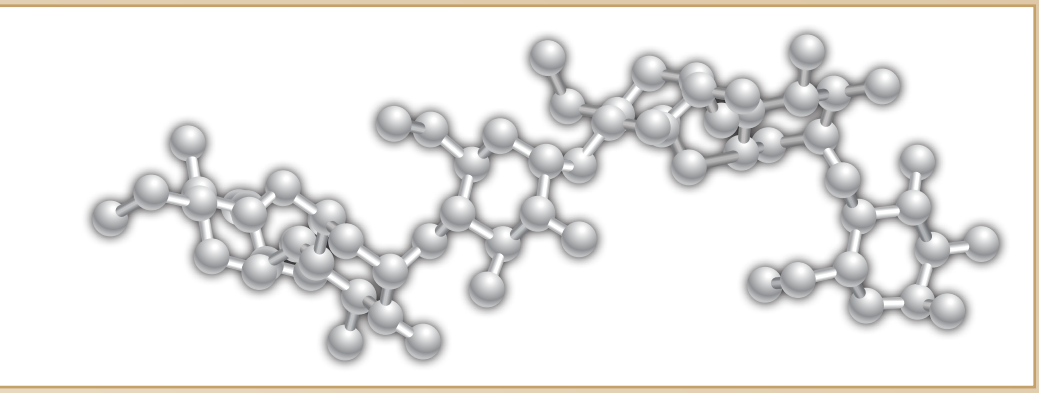
WHISTLER CENTER
for Carbohydrate Research

2021 ANNUAL REPORT

PURDUE UNIVERSITY | Food Science



3-D view of starch structure.

Industrial Members

(Members of 2021 Industrial Advisory Board)

Archer Daniels Midland

Cargill

General Mills

Grain Processing Corporation

Hayashibara

Mars Wrigley

Mondelēz International

Nestlé

Novozymes

PepsiCo


eppendorf

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Director's Statement

A warm welcome from the Whistler Center of Carbohydrate Research and to our 2021 Annual Report. It was a year of pretty much going back to normal in the pandemic time, as Purdue itself was committed to full face-to-face instruction. Masks were required, of course, but research and teaching were as close to usual. At the Whistler Center, we continued our educational and meeting interactions online with our member companies, and with quite good attendance. This included our May Board Meeting and fall Focus Meeting, May Belfort Lecture and Technical Conference, which we opened up to invited non-members, our six annual webinars, October Short Course on carbohydrates, and member annual visits.

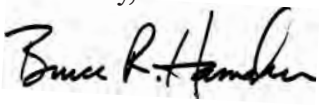
In summer 2021, one of our Center external faculty members, Senay Simsek, moved to Purdue as our new Food Science Department Head! We are thrilled to have her leadership, and for her continued involvement as a Whistler Center faculty member. In this year, we initiated a new project concept for working on research with our member companies with good success. We funded three new projects through the Center, designed around teams of three faculty members and scientists from companies. Two projects hit on aspects of carbohydrates and the gut microbiome, and the other on reactive extrusion to produce soluble fiber. Lisa Mauer's group continued a multiyear project on sugar reduction/replacement with new findings related to sugar and oligosaccharide properties in foods.

Food carbohydrates continue to be in the spotlight in both positive and negative ways related to nutrition and health. In the dietary fiber and prebiotic area, the Whistler Center has a strong gut microbiome program, and we have become known for our studies on dietary fiber structures related to gut microbiota function and health, and phytochemical effects. And we are part of the dynamic Purdue Applied Microbiome Sciences led by our own Steve Lindemann. At the same time, carbohydrates continue to be seen as contributing to the overweight and obesity epidemic, and many consumers see benefits from low carb diets. The Whistler Center has been at the forefront of understanding the details around quality and healthy carbohydrates, publishing this year that carbohydrates can elevate a satiety-related gut hormone for reduced food intake and weight gain. This is on top of our fundamental strengths in carbohydrate structure and function relationships in food texture, delivery systems, interactions with other constituents in foods, and even into the plant-based proteins.

In research, a high productivity indicator is that we had 128 published refereed journal papers in 2021, from 15 faculty members. Our faculty are very competitive in obtaining grant funding for their research, and looking back we had nearly $15 million of grants obtained by faculty in the last five years ($12.2 million federal, $1.6 million industrial). Internal Whistler Center funds provide important research seed monies and help maintain and buy new equipment. Whistler Center faculty and students obtained numerous awards in 2021, listed in Section D, and notably Steve Lindemann was promoted to Associate Professor, Lisa Mauer became an IFT Fellow, Senay Simsek was named as Dean's Chair in Food Science, and Yuan Yao is a Showalter Faculty Scholar.

As we move to 2022, remember that we have our annual Short Course in October with a hybrid face-to-face or virtual format. Please take a look at our 2021 Annual Report, and feel free to contact us with any questions.

Sincerely,



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


GLOVE
RECYCLING BIN

Summary of Major Research Accomplishments

Starches, Non-starch Polysaccharides and Cereals

J. BeMiller published an article on the effect of hydrocolloids on normal and waxy maize starches cross-linked with epichlorohydrin (*Food Hydrocolloids*). The research showed that the general effect of hydrocolloids on starch granule swelling was consistent between the normal and cross-linked starches. Differences in the effect were unrelated to whether the cross-linked starch had a negative surface charge.

B. Hamaker's group does mostly health-related research on starches and non-starch polysaccharides (see below), though also, with **O. Campanella,** structure-function studies related to texture and formulations. This year, a number of our joint papers were published in the texture/rheology area (see Part A in report), and recent works (such as incorporation of functional fibers into extrudates, changing material properties through polymer interactions) were finished and are being prepared for publication. In Project 4, work has advanced on fabricating soluble fiber matrices that have targeted function in the gut microbiome.

M. Martinez' group continues to perform studies to enhance the functionality of polysaccharide-rich food materials. His particular focus is on the "structure and function of polysaccharides," including their binding potential to plant secondary metabolites and the elucidation of their complex structural biochemistry using advanced MS- and NMR-based techniques. With regard to polysaccharide materials, he has recently studied how the functional properties of pectins extracted from hawthorn are influenced by drying temperatures (Project 24)

L. Mauer's group leads a Center-supported project on sugar reduction/replacement taking a materials science approach to manipulate and investigate food ingredient structures and functions, water-solid interactions, and amorphization and crystallization tendencies. Ongoing studies include investigations of the roles of sugars and oligosaccharides on the functional properties of starch (Project 28).

G. Narsimhan's group has completed a series of studies on the swelling of starch granules as a function of temperature and starch content, finding key relations between the likelihood of hydration for a given starch type, the relative growth of granules due to swelling, and the contribution of the granules to starch paste elasticity in the close-packing limit (Project 29). These studies require characterization of surface properties of starch granules and light scattering approaches that are commonly accessible. Further studies on this approach identified how changes to the hydration properties and continuous phase properties with the addition of sucrose and other disaccharides could also explain the starch granule swelling and contribution to paste elasticity within the same framework (Project 30). In addition to these studies on starch pasting behaviors, Dr. Narsimhan has also completed studies on the optimization of antimicrobial peptide action against pathogenic bacteria by using combined ultrasound treatments (Project 31).

S. Simsek's group has developed a research program focused on the integration of cereal quality with the structure-function relationships of carbohydrates to increase the utilization of cereals, legumes, and other underutilized crops and their byproducts in the baking industry. Industrial cooking processes can be used to enhanced extraction yield of soluble dietary fiber (SDF) from dry beans, but this can impact their functional properties. In collaboration with O. Campanella, a study was conducted on the effect of cooking processes on the molecular size distribution and flow behavior of soluble dietary fiber from dry pinto and black beans (Project 36). Cooking process resulted in fiber degradation, and calcium chloride added during heating and cooling processes at constant strain formed stronger interactions among the non-degraded polymers in raw samples. Results demonstrated the potential use of SDF from raw dry beans as an ingredient in heat-treated foods, such as baked goods. In a separate yet related project, the effect of fermentation and baking processes on the arabinoxylan structures was determined within wheat breads (Project 38). Arabinoxylan solubility, substitution rate, and fine structure all changed significantly during the various stages of fermentation and baking. S. Simsek's group has also conducted investigations related to processing and carbohydrate functionality in oat milk (Project 37). The rising popularity of plant-based dairy beverage substitutes can partially be attributed to the increase in plant-based or clean label foods. Heat treatment or flaking of groats impacted the physical characteristics of oat milk bases, while extraction parameters, such as water ratio and enzyme treatments, impacted yield and extract appearance. It was determined that amylase treatment must be conducted to ensure a high-quality oat beverage.

Y. Yao's group continued work on the modification and selection of carbohydrate-based (and other biopolymer) ingredients for food and pharmaceutical use. Ongoing studies characterized biopolymers using a molecular rotor (MR) approach (Project 39), which is able to determine physical changes in samples related to sample differences or processes. His group has also made progress in using chemically-modified phytoglycogen to formulate delivery systems for niclosamide, a potential antiviral therapeutic of COVID-19 (Project 40). These formulations with niclosamide showed substantial increase in its *in vivo* antiviral efficacy against SARS-CoV-2. In addition, progress has been made to explore novel functional food ingredients from plant sources (Project 41), and the group is developing a new food manufacturing system under the scope of "Advanced Manufacturing of Food" (Project 42).

Carbohydrates, Nutrition and Health

O. Campanella, along with international collaborators, has performed a combination of rheological analyses and mathematical modeling approaches to identify innovative and sustainable technologies to improve the efficacy and safety of polysaccharide-containing foods. This includes studies on dietary fibers obtained from fruit peels and other sources, their effects on food product properties during and after processing, and the ultimate impact on gut microbial growth (Project 1). Current work is underway on models to describe various factors, including viscosity and nutrient availability within the gut, contributing to the development of healthy gut bacterial communities.

B. Hamaker's group continues to work on both dietary fibers and the gut microbiome, and glycemic carbohydrates and their potential to directly activate the gut-brain axis for satiety, appetite control, and weight management. In the area of alignment of fiber prebiotics to resident gut probiotics or groups of bacteria with relation to health, they are active in investigating ways to identify fibers that support and promote beneficial gut bacteria and, in collaboration with Rush Medical School, have shown that a designed fiber mixture improved key biomarkers related to health in Parkinson's disease patients (Projects 5 and 6). In the glycemic carbohydrate area, with L. Reddivari, showed activation in mice of the gut-brain axis using a common food phenolic acid added to a starchy food, and a clinical study was begun in 2021 to test the direct triggering of the gut-brain axis with certain foods (Project 7). Slowly digestible carbohydrates were also shown to increase fat oxidation in mice and improve metabolic flexibility, and metabolic fuel utilization was also shown to be effected in Kenyan versus US study cohorts (Project 8).

S. Lindemann's research program continues to identify important physical and chemical structural elements that contribute to population shift and growth dynamics among gut microbial communities. Consumption of brans from grains contributes a significant dietary content of polysaccharides to the gut, including arabinoxylans. In a series of recent studies, arabinoxylans from different sorghum lines were shown to change the microbial diversity of consortia and to select for varying diversities of carbohydrases among these bacteria (Project 20). Such changes were highly specific to the sorghum line and to the pre-treatment with arabinofuranosidases, the latter of which increased growth selectivity. This approach is being translated to other grains, including wheats and ancient grains. As brans are poorly soluble in water, they are commonly consumed as particles with process-dependent sizes. In order to identify the importance of bran particle size and morphology, effects of milling operations on gut microbiota were identified in terms of the changing contents of solubilized carbohydrates from the particles (Project 21). Ongoing studies have demonstrated the importance of particle size after milling in relation to the bran source, with more recent studies indicating that changes in grain varieties with shifting agricultural production over generations has led to corresponding changes in gut microbiota. Availability of specific carbohydrate structures in dietary fiber sources is known to contribute to changing in gut microbiota communities. Accordingly, a series of studies in Dr. Lindemann's group has shown the complex relations between the relative compositions of glucans fed to a community of bacteria and the relative populations of taxa in those communities (Project 22). This is leading to further studies to demonstrate the importance of carbohydrate complexity in sustaining healthy microbial communities in the gut. Predictive mathematical models are also being developed and refined to describe the capacity of gut microbial communities to degrade inulins of varying chain length (Project 23).

E. Oh's group focuses on the fermentation of oligosaccharides by metabolically engineered yeast to alleviate functional bowel disorder symptoms (Project 32). Specifically, they are developing a new class of engineered yeast strains for targeted removal of undesirable carbohydrates in the dough fermentation process. The development of these designer microorganisms could reduce irritable bowel syndrome (IBS) symptoms and improve gut health for affected individuals.

L. Reddivari's group focuses on harnessing the bioactive compounds in foods to improve gut barrier function and prevent chronic inflammation, which is the underlying cause of many chronic colonic diseases. They are currently working on understanding the role of gut bacteria in the anti-colitic and anti-inflammatory properties of plant flavonoids in purple and red potatoes (Project 33), dietary fiber (Project 34) and anthocyanin and fiber complex (Project 35).

The focus is on understanding the interaction between polysaccharides and flavonoids and how the interaction influences the stability and bioavailability of flavonoids and their role in maintaining gut barrier function in health and disease.

Chemical Structure and Functions of Polysaccharides

B. Reuhs and A. Terekhov run the analytical core facility at the Whistler Center dedicated to complex carbohydrate structural analysis. With other Whistler Center faculty, the group provides expertise and studies on non-starch polysaccharide structures related to physicochemical and rheology functionality, and gut microbiota fermentation properties.

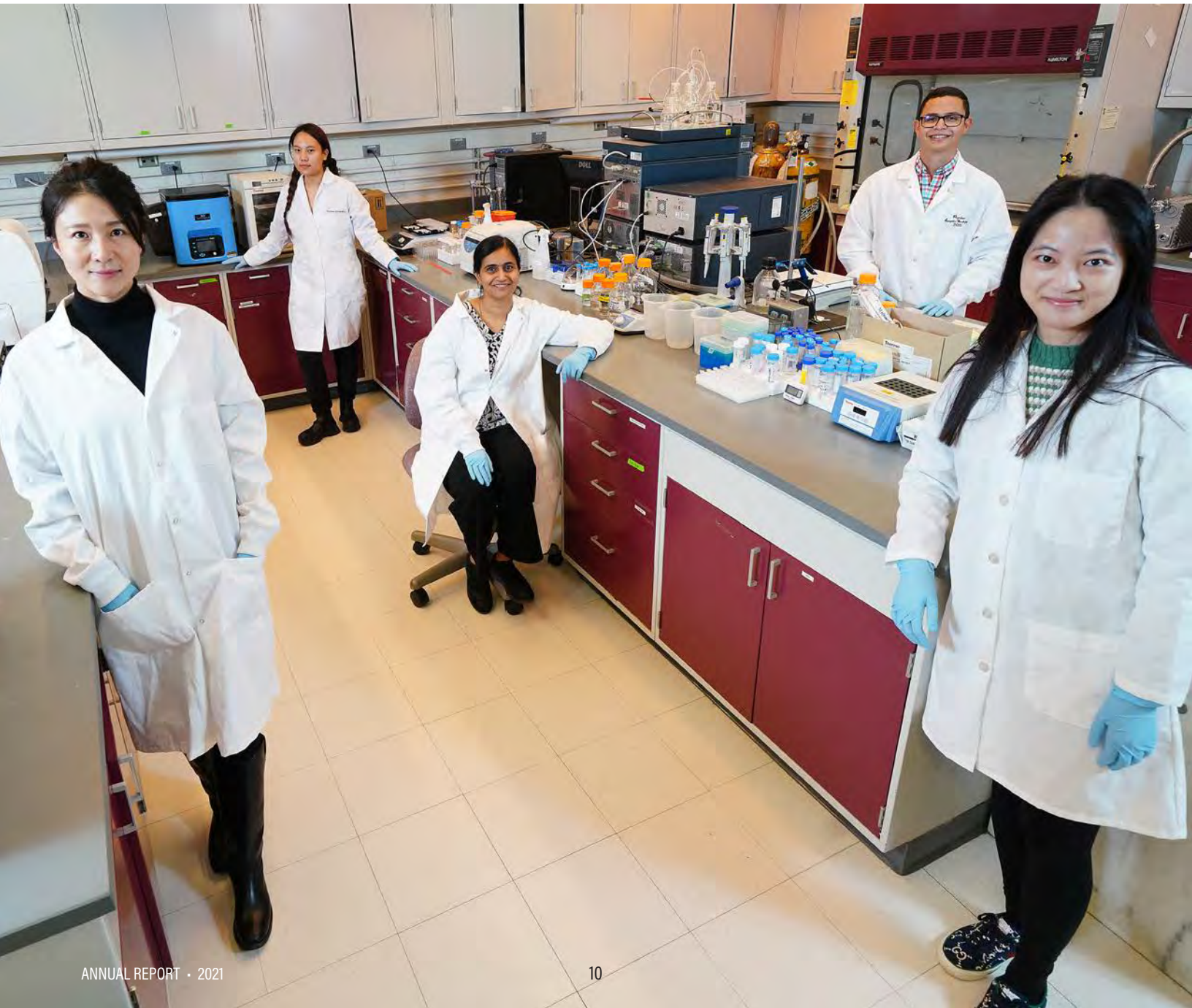
Emerging Food Processes

O. Campanella continues to develop improved understanding of how the efficacy of processing techniques is influenced by the food material composition of polysaccharide-containing foods. In the past year, his group has refined mathematical models to describe inactivation of pathogenic bacteria and bacterial spores in food materials during non-thermal processing techniques (Project 2) and the detachment of fouling material on processing surfaces by impinging microbubbles (Project 3). Impacts from these studies will contribute to improved recommendations for ingredient selection, formulations, processing, and cleaning approaches for polysaccharide-containing foods. Additionally, with **B. Hamaker**, research is ongoing on how to incorporate viscoelastic zein web-like networks into commodity plant-based protein meat and cheese analogues to improve functionality (Project 9).

M. Martinez' group aims to deliver breakthrough research about mechanisms, analytical procedures, processing solutions, and functionality of food. He relies on coherent and focused food system approaches on the selection of appropriate processing techniques for specific components to find common ground for human health (e.g., Project 25) and environmental sustainability (e.g., Projects 26 & 27). These projects involve the extrusion techniques to improve stability of oil seed cakes, to produce meat analogues from hemp seed protein, and to prepare bioplastics.

O. Jones' research identifies the interfacial and structural contributions of colloidal materials assembled from proteins in polysaccharide-rich materials, including the use of processing technologies to facilitate their implementation in food. A collaborative project with Drs. Campanella and Hamaker on the physical processing of maize protein (Project 10) ended this year. Final results from the project showed that oven-heating of maize protein offers improvements for use in gluten-free formulations, yet extrusion processing showed greater promise. Other studies with maize protein used enzymatic hydrolysis and conjugation with polysaccharide chains to improve aqueous solubility, emulsifying, and foaming properties (Project 11). Recent developments in this project demonstrated the efficacy of heat-induced conjugation of hydrolyzed maize protein with uncharged polysaccharide chains with a significant increase in functional properties. Two recent projects initiated in the second half of 2021 will identify combinations of extrusion and enzymatic hydrolysis procedures to improve desirable properties of bean flours (Project 12, a collaborative project with Drs. Campanella, Simsek, and Martinez) and identify conditions and useful structures developed by the associative interactions of dairy proteins with gellan gum (Project 13).

J. Kokini's group continues to identify important input parameters and analytical approaches for achieving desirable textures and stability of food products. Recent projects with pea protein have shown how its contributions to rheology and emulsifying properties could be predicted based on its primary and tertiary structure using bioinformatics (Project 14). Emulsifying functionality of pea protein could also be enhanced by use of cold denaturation processes as an alternative to traditional processes (Project 16). Contributions have also been made to the improved understanding of rheological properties of food materials by lesser-utilized regions of commonly available rheometry devices, including medium amplitude oscillatory shear measurements of dough samples (Project 15) and nonlinear evaluation of large amplitude oscillatory shear measurements of cream cheeses (Project 17). This latter approach is also being utilized to identify the role of protein secondary structure to gel properties of pulses (Project 19). In a recently completed series of non-related studies, spun fibers of soy protein were decorated with metal particles to enhance responsiveness to raman spectroscopy and potentially serve as an analytical sensor (Project 18).



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Bernhard Van Lengerich	Adjunct Professor

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Grethel Teresa Choque- Delgado	Hamaker	September 2021-October 2021
Yunus E. Tunçil	Hamaker	June 2021-November 2021
Nana Wu	Hamaker	January 2020-January 2021

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Felipe Rocha	Jones	March 2020-February 2021

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Faculty

James N. BeMiller

General Research Areas

- Starch
- Carbohydrate chemistry

Specific Research Areas

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

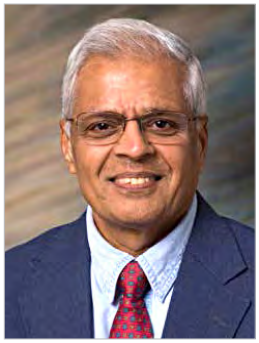
Osvaldo H. Campanella

General Research Areas

- Process modeling
- Rheology
- Material structure and texture
- Extrusion

Specific Research Areas

- Application of rheology to food science and food engineering
- Mathematical modeling of food process operations
- Online rheological techniques
- Rheology of biomaterials
- Dough rheology
- Rheology of dairy products
- Characterization of material structure and texture; relationship to rheological properties
- Effect of glass transition on product texture
- Bioplastics: Uses of food processing wastes
- Reactive extrusion in the production of foods and bioplastics
- Production of plant base meat analogs by extrusion technology



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

Mario G. Ferruzzi

General Research Areas

- Development of methods for determination of micronutrients and phytochemicals (carotenoids and phenolics) in complex food and biological matrices
- Characterization of food matrix factors that optimize stability and bioaccessibility of micronutrients and phytochemicals
- Exploration of genetic, food matrix and ingestive factors that impact bioavailability and metabolism of phytochemicals from plant foods using preclinical and clinical models

Bruce R. Hamaker

General Research Areas

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

Specific Research Areas

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

Owen G. Jones

General Research Areas

- Energy and stoichiometry of polysaccharide interactions with other materials
- Determination of size, morphology, and stability of colloidal suspensions
- Atomic force techniques to determine morphology and elasticity of sub-millimeter material

Specific Research Areas

- Role of chemical and physical structures in defining protein-polysaccharide interactions
- Controlled assembly of fibrous or particulate colloids from polysaccharides or proteins
- Emulsifying properties of colloidal materials
- Contributions of colloidal polysaccharide/protein assemblies to films, gels, or pastes

Jozef Kokini

General Research Areas

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

Stephen Lindemann

General Research Areas

- Dietary fiber impacts on gut microbiome diversity, structure, and function
- Species-resolved metagenomics and metabolism
- Genomic mechanisms of polysaccharide fermentation
- Carbon, nitrogen and energy cycling by gut microbiota
- Microbiome-mediated impacts on host physiology
- Microbial systems ecology

Specific Research Areas

- Particle size and processing method impacts on microbial metabolism of wheat bran
- Arabinoxylan structure influences on gut microbiome structure and function
- Predictive ecology of gut carbohydrate metabolism
- Fiber targeting to gut microbes
- Microbial division of labor in polysaccharide degradation

Mario Martinez

General Research Areas

- Glycoscience
- Food structuring
- Binding interactions and digestion models

Specific Research Areas

- Structural elucidation of polysaccharides
- Non-covalent binding between small metabolites and food macromolecules
- Food and agricultural waste valorization through technology development
- Structuring of plant-based meat analogues
- Organocatalytic derivatization of food biopolymers

Lisa J. Mauer

General Research Areas

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

Specific Research Areas

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

Ganesan Narsimhan

General Research Areas

- Emulsions and foams
- Biopolymer interactions

Specific Research Areas

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

Eun Joong Oh

General Research Areas

- Fermentation science
- Metabolic engineering
- Synthetic biology

Specific Research Areas

- Biotechnological production of food ingredients and value-added chemicals using engineered microorganisms
- Multiplex CRISPR/Cas9-based genome engineering
- Microbial cell factories for industrial bioprocesses
- Regulatory networks in yeast
- Engineering probiotic strains for human health applications

Lavanya Reddivari

General Research Areas

- Plant bioactive compounds and health
- Flavonoids and carotenoids
- Gut microbial metabolism

Specific Research Areas

- Anti-inflammatory plant bioactives for improved gut health
- Reciprocal interaction of gut microbiome and plant bioactives in health and disease
- Interactions between plant bioactives and fiber/starch in the modulation of gut bacteria

Bradley L. Reuhs

General Research Areas

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

Specific Research Areas

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

Senay Simsek

General Research Areas

- Structure-function relationships of carbohydrates
- Grain and legume quality & utilization
- Carbohydrates in the baking industry
- Industrial hemp utilization

Specific Research Areas

- New carbohydrate functional ingredients
- Innovative uses for processing byproducts and waste materials
- Biodegradable packaging films
- Characterization and utilization of industrial hemp grain and byproducts
- Variation and functionality of sorghum carbohydrates and bioactive compounds

Yuan Yao

General Research Areas

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

Specific Research Areas

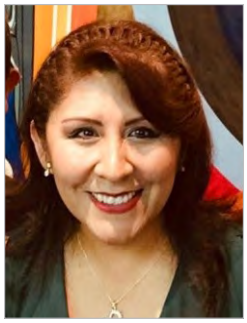
- Construction and characterization of nano-biomaterials
- Stabilization, solubilization and delivery of active ingredients
- Genetic, enzymatic and chemical modifications of starch
- Functional food ingredients
- Carbohydrate microanalysis
- Evaluation and removal of pathogen biofilms
- Roll-to-roll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

Adjunct Faculty

Yonas Gizaw, PhD, is Principal Scientist at The Procter and Gamble Co. Currently, he is technical leader for Chemistry Transformative Platform Technologies in Corporate R&D. Dr. Gizaw is a 20-year veteran of P&G with broad experience in biopolymers, nanotechnology, polymers physical chemistry, surfactants and colloids. He spent about eight years in Snack and Beverages, where he supported technology development for beverages (Sunny D) and Snacks (Pringles), then moved to the Fabric Care Strategic and Innovation division, where he was responsible for development of strategic technologies for cleaning and fabric feel (Downy & Tide), etc. The last several years Dr. Gizaw has focused his research on physical chemistry of wetting phenomena to develop disruptive technologies in Superhydrophobic and Superomniphobic surfaces. Prior to joining P&G, Dr. Gizaw received his doctoral degree from Purdue University in synthetic carbohydrate chemistry.

Bernhard Van Lengerich, PhD, is a former Chief Science Officer and VP Strategic Technology Development at General Mills and former acting CTO at Beyond Meat. After apprenticeships as artisan baker and pastry chef, he studied Food/Biotechnology at the Technical University of Berlin, Germany, and completed his PhD thesis in the field of extrusion with summa cum laude. He joined Werner and Pfleiderer (Coperion) in New Jersey as Senior Process Engineer for Extrusion, then joined RJR Nabisco, New Jersey, as Director of Extrusion Research. He subsequently assumed the position of Vice President of Global R&D Food at the Buehler Group in Switzerland. In 1994, Bernhard joined General Mills, Inc. in Minneapolis. He led all GMI Extrusion initiatives and GMI's Game-Changer Innovation Program and created a novel GMI Technology Venturing initiative, enabling faster and higher impact innovations. As Chief Science Officer and VP Technology Strategy, he was responsible for Science and Technology Development across the company. Bernhard retired from General Mills in 2015. He is the inventor or co-inventor of more than 150 patents and patent applications, holds an Honorarium Professorship at the Technical University of Berlin, Germany, teaching Extrusion Science and Technology, and is a Fellow of the Institute of Food Technologists in Chicago. Bernhard was an invited participant in discussions at the White House Office for Science and Technology Policy on global protein security under the Obama administration. In 2016, he joined Beyond Meat in an advisory role as acting CTO and Head of R&D, leading the development and launch of the first Beyond Burger in 2016. He served as a board member of Beyond Meat until 2021. Bernhard is the founder of Seeding the Future Foundation, a 501(c) (3) organization focusing on seeding and supporting impactful innovations that help improve our food system. He also initiated the annual Global Food System Challenge, which is funded by the Seeding The Future Foundation. In addition, Bernhard serves as board member of the German Institute of Food Technology (DIL), Bountifield International, and is an advisory board member of S2G Ventures, Brightseed Bio, PetriBio, UKKO, and several organizations in the US and Europe.

Visiting Professors



Grethel Teresa Choque-Delgado received her BS in Food Engineering from the Universidad Nacional de San Agustín de Arequipa (Peru). She earned her MS in Business Administration at Universidade Federal do Rio Grande do Sul and PhD in Food Science at Universidade Estadual de Campinas (Brazil). She was a visiting scholar in 2021 in Dr. Bruce Hamaker's lab for six weeks to conduct part of the Peru NEXUS project. She was trained on the analysis of heavy metals and *in vitro* fecal fermentation regarding heavy metal effect on the gut microbiota.

Yunus E. Tuncil completed his PhD with Dr. Bruce Hamaker in the Food Science Department and Whistler Center at Purdue University in 2016. He then joined the laboratories of Drs. Stephen Lindemann and Hamaker as a postdoctoral research associate, where he worked on dietary fiber chemistry and its effect on colonic microbiota structure related to human health. Dr. Tuncil is currently an associate professor in the Food Engineering Department at Necmettin Erbakan University in Turkey, where he continues working on dietary fiber and colonic microbiota interactions. He is currently a PI of four different governmental-supported projects on the fiber-microbiome area. In 2021, he was a visiting professor in the labs of Drs. Lindemann and Hamaker.

Nana Wu completed her BS and MS degrees in Food Science from Henan University of Technology in 2005 and 2008, respectively. She obtained her PhD degree from South China University of Technology in 2012. She joined Dr. Bruce Hamaker's group as a visiting professor in January 2020. Her research focus was on the dietary fiber chemical and structural analysis and effect on the human gut microbiota in Dr. Hamaker's group. She continued her research in Dr. Hamaker's lab until January 2021. She was recently promoted to professor in Academy of National Food and Strategic Reserves Administration in China. In this research institute, her research focuses on the relationship and regulation of carbohydrate structure and function in cereals, and cereal carbohydrate health products.

Visiting Scientists

Antonio Jose Vela Corona received his BS in Chemical Engineering from Del Valle University in Guatemala. He continued in a master's program in Food Science at the University of Valladolid, in Spain, where he is currently working on his PhD. He had the opportunity through support of the IMFAHE Foundation to come to Purdue University as a visiting scholar in Dr. Bruce Hamaker's laboratory in 2021 to conduct research related to the molecular structure of starches by size exclusion chromatography. His doctoral research is mainly focused on the physical modification of gluten-free flours by ultrasound treatments.

Mirian De Campos Costa received her bachelor's degree in Nutrition from the Universidade Federal de Vicosa (Brazil), with a collaborative period in Southern Illinois University Carbondale. She earned her master's in Nutrition Science from the Universidade Federal de Vicosa and currently is a PhD student in the Food Science department of that university. In 2021, she joined Dr. Hamaker's group for a year training period as a visiting scholar. Her research is mainly focused on investigating the effects of bioactive compounds and fibers on the gut microbiota.

Jaime Fernandez completed his programmatic studies in Food Engineering at the University Fundación Tecnológica Jesús Oviedo Pérez in Colombia in 2020. He worked as a researcher during his undergraduate thesis at the same university before coming to Purdue University. In 2021, he received a "NEXO HUILA" scholarship to join Dr. Jozef Kokini's lab as a visiting scholar to finish his undergraduate thesis and work on the development of biodegradable materials for fruit preservation.

Wanying He is a visiting Food Science PhD student from Huazhong Agricultural University in China. Her dissertation is on the structure and modification of corn protein, including zein. Wanying received funding from the China Scholarship Council to study at Purdue University in the laboratory of Dr. Owen Jones for two years. She began her studies at Purdue in August 2019 and has been identifying techniques to improve zein functionality by chemical and enzymatic treatments, including interactions with polysaccharides. Wanying plans to graduate in June 2022 from Huazhong Agricultural University.

Yusong Jin completed her PhD in Northeast Forestry University in China in December of 2021. She joined Dr. Reddivari's group as a visiting scholar for one year (January of 2020 to January of 2021). Her research focuses on plant food bioactive components, and low-grade inflammation-driven chronic diseases. She is now actively looking for a postdoc position.

Seher Serin Karayiyen received her MS (2013) degree and PhD (2019) from Department of Food Engineering at the University of Mersin in Turkey. Her research focused on determination of the effects of the *in vitro* digestion and *in vitro* fermentation properties of different types of resistant starches as related to human health. In December 2021, she joined Dr. Bruce Hamaker's group as a visiting scholar for a year. Her research focuses on the effect of different types of resistant starches on the delay of fermentation in the large intestine and effect on the gut microbiota.

Veda Krishnan is a visiting scientist from Indian Council of Agricultural Research (ICAR), India. She joined Drs. Bruce Hamaker and Lavanya Reddivari's laboratories in April 2021 for twelve months as a Fulbright scholar. Her research focused on the role of natural food-derived flavonoids in activating the gut-brain axis through sweet-bitter signaling.

Felipe Rocha graduated from the Federal University of Technology - Paraná in Brazil with a BS in Food Engineering in 2017 and earned his MS in Food Technology in 2018 at the same university. In 2020, he joined Dr. Jones's lab group as a visiting scholar for a year to conduct part of his PhD research. His research focuses on complexation of bioactive compounds with biopolymers in order to improve their properties for application in food systems.

Graduate Students

Adriana Maribell Aguilar Torres is a PhD fellow at Department of Food Science, AU FOOD (2021-, Aarhus University). Her research focuses on interactions between polysaccharides and polyphenols (secondary metabolites of plants) and development of food packaging. She holds a master's degree in Molecular Nutrition and Food Technology (2020, Aarhus University, Denmark) and a bachelor's degree in Food Science (2012, Universidad Autónoma de Nuevo León, México). Her research topics include interactions between secondary metabolites of plants (anthocyanins and phenolic acids) and microencapsulation of fish oil. Besides her academic career, she took the opportunity to work in the food industry for 2.5 years (Mondelez International and Bachoco México).

Miguel Alvarez Gonzales is a graduate student in the Lindemann lab. Prior to starting his PhD, Miguel obtained his bachelor's degree in Food Science and Technology from Zamorano University, Honduras, trained for a year in molecular biology techniques and bioinformatics, and completed his master's degree in Food Science with an emphasis in carbohydrate chemistry. Now, in the Lindemann lab, he uses the structure and function of carbohydrates, chromatographic techniques, and bioinformatics to characterize wheat bran interactions with the gut microbiome.

Emmanuel Ayua graduated from Moi University in December 2011 and earned a MSc in Community Nutrition from the University of Eldoret. He joined Dr. Bruce Hamaker's lab in 2016 and worked on effect of extrusion on the fermentation of dietary fibers and extrusion processing of cereals in developing countries. Emmanuel completed his PhD in Food Science in May 2021 and returned to the University of Eldoret as an assistant professor. He is continuing to work with Dr. Hamaker in the USAID Food Processing Innovation Lab.

Wenqiang Bai received his BS (2016) from Qingdao Agricultural University, China, and MS (2019) from Chinese Academy of Agricultural Sciences, both in Food Science.Now he is a PhD fellow (from October 2020 to September 2023) in the Martinez group at Department of Food Science, Aarhus University. His PhD research mainly focuses on understanding the structure-compatibilization relationships of pectic polysaccharides for food packaging applications.

Nuseybe Bulut completed her BS degree in July 2014 at the Food Engineering Department, Istanbul Technical University (ITU), Turkey. She joined Dr. Bruce Hamaker's lab group in January 2017. Her MS research focused on fabrication of plant cell wall-like materials and their impact on the human gut microbiota, and she graduated in fall 2019. She continues her PhD studies with Dr. Hamaker in the area of dietary fiber and the gut microbiome.

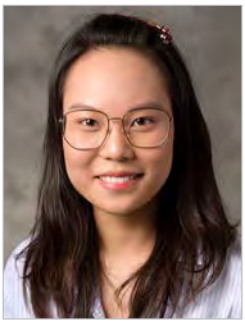
Jingfan Chen received her BS in Food Science from Purdue University in 2015. She joined Dr. Yao's lab in 2016 to pursue her PhD degree. Her main research focus was on phytoglycogen and its derivatives for food and pharmaceutical applications. She has also studied the use of a molecular rotor for biopolymer characterizations. She graduated in March 2021 and now works in a food ingredient company.

Zhuoran Chen received her BS in Food Science from Purdue University in 2020. She joined Dr. Yao's lab as an intern in 2020. She then joined the MS program in 2021. Her research topics include novel plant-based functional food ingredients and innovative food manufacturing with a focus on plant-based proteins.

Jayani Maddakandage Dona earned her BS degree in Food Science and Nutrition in 2017 from Wayamba University of Sri Lanka. At North Dakota State University, she worked under the advisement of Dr. Senay Simsek on nutritional quality of ancient wheat species and graduated with her MS in summer 2020. Currently, she is a PhD candidate in the cereal science program at North Dakota State University under the supervision of Dr. Senay Simsek. Her research focus is on dietary fiber and the gut microbiome.

Enrico Federici earned his BS and MS degree in Food Science and Technology in 2014 and 2016 from the University of Parma. Enrico earned a PhD in Food Chemistry in the laboratory of Dr. Owen Jones in February 2021. His research focused on the improvement of gluten-free products with the use of novel protein preparations and assemblies. Currently, he works as an innovation scientist for Beyond Meat Co. Enrico is interested in plant proteins functionality and is an active member of the IFT protein division.

Monique Felix completed her BS in Biochemistry at Claflin University in May 2018. Her BS thesis was aimed at making beta-glucosidase more thermostable, which would make biofuel more cost effective, by deleting the costly cooling system used to prevent enzyme degradation. Monique completed her MS in Agricultural Regulation at University of Arkansas at Pine Bluff. Here, her research has included characterizing the role of the IncFIB plasmid in *Salmonella* pathogenicity. She joined Dr. Lindemann's lab in January 2021. Her PhD research focuses on determining the traits that influences competitiveness for carbohydrates in the gut microbiome.



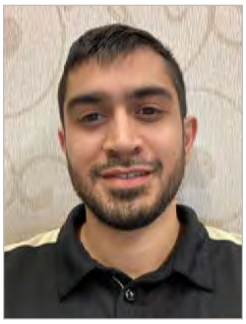
Wenyi Fu received her BS degree from the Department of Food Science at Purdue University in 2019. She then joined Dr. Lavanya Reddivari's lab group to pursue her MS. Her area of interest is Food Chemistry, and current research focused on how dietary fibers and polyphenols affect the human gut microbiota and gut health. Wenyi graduated in December 2021.

Wanxiang Guo received her bachelor's degree in Food Science and Engineering from South China Agricultural University in 2018. Then she got her master's degree in Food Science and Technology from the South China University of Technology under the supervision of Professor Weizheng Sun in 2021. During her master's period, she worked on the effect of different processing on the stability of anti-nutritional factors in soymilk. She is now a PhD student in Dr. Mario Martinez's group at Aarhus University in Denmark. She is investigating the effect of processing on the molecular structure of the main biopolymers present in cereal grains and their potential to become biodegradable polymers for packaging applications.

Anna Hayes received her BS in Food and Nutrition Science and her BA in Spanish from Saint Catherine University (Saint Paul, Minnesota) in May 2014. Anna joined Dr. Bruce Hamaker's lab as a direct bachelor's-to-PhD student in the Purdue Food Science Department in August 2014. Her research focused on investigating the slow digestion and satiety properties of pearl millet grown in sub-Saharan Africa, the metabolic consequences of carbohydrates with differing digestion rates, and the implications of starch fine structural features on digestibility and texture applications. Her work has helped identify characteristics of glycemic carbohydrates that impart a slow digestion property and made strides to elucidate how they can be leveraged to design foods with targeted physiological and metabolic outcomes. She completed her PhD in spring 2021 and is now a postdoc at the University of Southern California studying diet, memory function, and appetite control.

Micaela Hayes received her PhD from North Carolina State University under the advisement of Dr. Mario Ferruzzi. Her doctoral research characterized the influence of genetics and food processing on the bioaccessibility of carotenoids and chlorophylls from spinach. She now works as an innovation analyst on the innovation advisors team at RTI International, where she consults with food and agriculture clients to assess product and technical feasibility, scout new technologies, and identify new market opportunities to direct client's business decisions.

Harrison Helmick is a PhD student in the Department of Food Science at Purdue University under the guidance of Dr. Jozef Kokini. His research focuses on using bioinformatics to develop structure-function relationships of plant-based protein to understand emulsification, gelling, and texturization in extrusion below 0°C. Prior to Purdue University, Harrison studied at Kansas State University and obtained a degree in Bakery Science. This turned into a career at Bimbo Bakeries ,where he worked in production and process improvement. After graduation, he hopes to work with an innovative company that incorporates data into their decision-making process to drive the business forward.



Enosh Kazem completed his BS in Food Science from Purdue University. His MS thesis project with Dr. Hamaker investigated prebiotic efficacy of tubers, grains, and pulses in whole food form compared to isolated fructo-oligosaccharides with an emphasis on inter-individual human microbiota response variations, defending in December 2020 and staying in the Hamaker group through June 2021. He has also been a part of several projects studying various prebiotic sources and their effect on human fecal microbiota, focusing on human digestion simulation and fecal microbiome fermentation methods.` He has experience in product development in the food industry focused on "digestive wellness" products.

Anael Kimble graduated from McGill University in 2017 with a BSc in Food Science and specialization in Food Chemistry. She spent four years working in the food industry in quality and food safety before joining Dr. Jones' lab in fall 2021. She is currently working on reactive extrusions on bean flour with the joint supervision of Dr. Campanella and Dr. Simsek.

Louie Le completed her BS degree in Food Science at Purdue in 2021. She joined Dr. Jozef Kokini's lab in 2020 as an undergraduate research assistant and she is pursuing her MS degree in the same lab. Her research focuses on nonlinear rheological properties of biopolymers.

Dahye Lee completed her BS degree in February 2018 in Food Engineering and Biotechnology from Dongguk University in South Korea. She earned her MS degree in the same department. Her research was about the anti-biofilm effect of bacteriocins produced by lactic acid bacteria in fermented food. She then worked for a typhoid vaccine clinical trial as a research assistant in the International Vaccine Institute. She joined Dr. Oh's lab in 2021 to do her PhD and her research focuses on engineering *Saccharomyces cerevisiae* metabolic pathways to get value-added chemicals from agricultural and forestry residues.

Ana Magallanes López completed her BS in Agroindustrial Engineering in fall 2015 at Chapingo Autonomous University in Mexico. Then, she worked as a research assistant in the Wheat Quality and Chemistry Laboratory at The International Maize and Wheat Improvement Center (CIMMYT). In spring 2017, she joined Dr. Simsek's lab At North Dakota State University to pursue graduate studies. She worked on the fate of deoxynivalenol during wheat wet-milling and characterization of the DON-free extracted starch and gluten and graduated with her MS degree in fall 2018. In spring 2019, she started her PhD, continuing under the advisement of Dr. Simsek at NDSU. She is currently working on extracting soluble dietary fiber from dry beans to study how its composition interacts with the immune system during a chronic condition, such as obesity. She plans to graduate in spring 2022.

Iván Misael López Rodulfo received his BS in Chemical Bacteriology and Parasitology from the Universidad Autónoma de Nuevo León (México) in 2019. Later, he earned his MS in Biomedical Physics and Engineering from Centro de Investigación y Estudios Avanzados (México) in 2021. Following graduation, he continued working as a research assistant at the same institute studying drug delivery systems. Recently, he joined the Martinez lab to pursue his PhD, where he will focus on studying non-covalent interactions between plant cell walls and compounds of interest such as flavonoids.

Rosa Lopez completed her bachelor's degree in Biotechnology at the Monterrey Institute of Technology and Higher Education in 2015. Later she obtained a master's degree from the Center for Research and Assistance in Technology and Design of the State of Jalisco (CIATEJ), Mexico. Her research focused on mucoadhesive polymeric films and emulsions for the delivery of bioactive compounds. She joined Dr. Hamaker's lab in fall 2021 to pursue her PhD degree. Her research focuses on the formation of starch-based complex materials and their evaluation to reach the small intestine and colon and activate physiological systems.

Mehdi Marashi received two MS degrees in Civil Engineering from University of Tehran and Purdue University before joining Dr. Stephen Lindemann's research group in 2020. His research focus was on numerical modeling of nonlinear and stochastic systems, and now he is working on modeling the ecology of microbial competition for varying oligosaccharide structures.

Cindy Mayorga completed her BS degree in Food Engineering at Universidad Tecnologica de Panama in 2016. She worked as a research assistant during her bachelor's thesis at the same university before coming to Purdue University. In 2019, she received a Fulbright scholarship to join Dr. Jozef Kokini's lab to pursue her MS and work on the development of biosensors.

Zulfiqar Mohamedshah earned his BS in Chemistry from the University of Virginia in 2018. Following his undergraduate career, Zulfiqar joined Dr. Ferruzzi's group at the Plants for Human Health Institute as a research technician. He continued his research within the Ferruzzi lab in 2019 as a graduate student. Zulfiqar's research focused on comparing the bioaccessibility and bioavailability of phenolic species between grapes and grape juice, completing an MS in Food Science in 2021 at North Carolina State University. In 2021, Zulfiqar joined the Devaraj and Komor research groups at the University of California, San Diego, as a PhD student.

Edward Moncada received his BS in Food Science and Technology from Zamorano University, Honduras. He came as a visiting scholar in 2019 as part of his undergraduate program and returned to Dr. Lavanya Reddivari's lab in 2021 to pursue his master's degree. His research focuses on dietary fiber and their influence in gut health, assessing fiber tolerability and modulation of gut bacteria.

Farzaneh Nasrollahzadeh completed her B.Sc. in Food Science and Technology in September 2013 at Ferdowsi University of Mashhad (FUM), Iran. In the same year, she initiated her MSc. at FUM, where she majored in Food Chemistry and conducted research on "conformational changes of proteins upon Maillard reaction." She joined Dr. Mario Martinez's team in 2019 at University of Guelph, Canada, to start her PhD journey on understanding plant protein structure-function relationships during wet extrusion and the fabrication of new types of fibrous plant-based meat analogues.

Vignesh Nathan completed his BS in Health and Disease (Biology) from Purdue University in May 2021. His undergraduate research focused on using probiotic feed additives to improve swine nutrition and health. He has also worked as an intern at B2S Life Sciences developing a COVID-19 antibody test. He joined Dr. Lavanya Reddivari's Lab in August 2021 to pursue a MS in Food Science;; his current research aims to understand the role various anthocyanins play in improving gut barrier integrity in piglets during early weaning stress.

Mai Nguyen received her BS in Microbiology and Food Safety at the University of Arizona in 2020. Her previous research experience was related to the prevalence of foodborne pathogens in water sources. Mai joined Dr. Stephen Lindemann's lab in fall 2020 and is pursuing a MS degree in Food Science. Her research is focused on the effect of resistant dextrins on the diversity of the gut microbiota.

Adrianna Pilch received dual BS degrees in Food Science & Human Nutrition and Chemistry at the University of Illinois at Urbana-Champaign in May 2020. She joined Dr. Lisa Mauer's lab in August 2020 to pursue her MS in Food Science. Adrianna is currently researching the effects of different forms of vitamin C on wheat starch properties.

Sarah Pitts received her BS in Biochemistry from Purdue University in 2019. She joined Dr. Lisa Mauer's lab group in 2019 to pursue a MS in Food Science. Sarah's research focused on sensory analysis of bakery products formulated with oligosaccharides. Sarah graduated in October 2021 and is now working in Research and Development on the Sensory and Consumer Insights team at Hershey.

Anurag Pujari obtained his BS in Industrial Microbiology and MS in Microbiology from the University of Pune, India. He joined the Diet-Microbiome Interactions Laboratory under Dr. Lindemann in spring 2021. His research focuses on the development of chemical probes that mimic certain characteristics of polysaccharides to study the microbial transport and hydrolysis traits as a response to consumption of these polysaccharides.

Adam Quinn joined Dr. Stephen Lindemann's lab as a PhD student after having completed his BS and MS in Food Science from Brigham Young University. He is currently investigating impacts of wheat genotypes on gut microbiota fermentation within the context of fiber and microbiome interactions. Adam enjoys cross-disciplinary projects that have foundations in agriculture.

Monica Richmond graduated in 2019 from North Carolina State University, receiving two Bachelor of Science degrees in Food Science and Bioprocessing Science. Currently, Monica is a master's student working in Dr. Bruce Hamaker's lab, focusing on the effects of viscosity on the gut microbiome concerning the utilization of dietary fibers. Her thesis focuses on the performance of *Bacteroides thetaiotaomicron* under various viscosity conditions.

Arianna Romero Marcia received her BS in Food Science and Technology from Zamorano University, Honduras. She joined Dr. Stephen Lindemann's lab as an intern in 2017 and came back in 2018 to pursue her MS in Food Science related to how glucans' chemical structure modulates the human gut microbiome structure and function. She graduated in May 2021 and is currently working on the Salty Snacks Division of Kellogg North America, focused on Pringles.

Kayla Roy earned her bachelor's degree in Microbiology at the University of Maryland, College Park. She joined Dr. Reddivari's lab in 2021 to pursue her interest in functional foods and is working toward her master's degree. Her research focuses on determining a mechanism for anthocyanin's bioactivity in inflammatory bowel syndrome.

Kasper Brandhøj Skov received his MS in Chemistry and Biotechnology Engineering at Aarhus University in January 2022. His MSc thesis approached the development of anisotropic structures using a combination of proteins and starch and extrusion technology. He is now a PhD student in Dr. Martinez's group working on chemo-mechanical routes to upcycle the stale bread waste matrix into high-performance biomaterials.

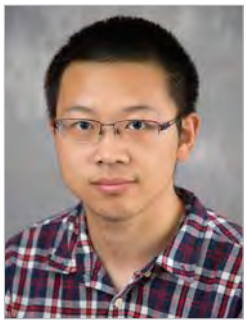
Paige Smith completed her BS degree in Chemistry at Waynesburg University in May 2021. She joined Dr. Lisa Mauer's lab in August 2021 to pursue her MS degree in Food Science. Paige's current research involves preconditioning different starches in oligosaccharides to modify the functionality of the starch by altering their physiochemical and thermal properties.

Jacob Thompson earned his bachelor's degree in Materials Science and Engineering from Michigan Technological University in May 2019. However, he soon discovered a passion for nutrition and decided to pursue it in the Interdepartmental Nutrition Program at Purdue. He joined the Lindemann lab in fall 2020 and is focusing on developing computational models to predict bacteria metabolism. The goal is to further understand how genetics influence gut microbiome ecology.

Pablo Torres-Aguilar received his MS in Nutritional Sciences from the University of Illinois at Urbana-Champaign and completed his dietetic internship at Beaumont Health System in Royal Oak, Michigan. At Illinois, he worked with Dr. Juan Andrade, examining the effect of potential fortification strategies for iron delivery in Guatemala, and subsequently with Dr. Angela Wiley, assessing food insecurity and the impact of environmental factors on the diet patterns of Latinos in the U.S. He joined Dr. Hamaker's group in fall 2014 and is working toward completing his PhD in the area of slowly digestible carbohydrates, postprandial glycemic control, and metabolic flexibility, with an anticipated graduation date of spring 2022.

Travis Woodbury received a BS in Food Science from Brigham Young University-Idaho in 2018. He joined Dr. Lisa Mauer's lab as an MS student in 2018 and bypassed to the PhD program in 2019. Travis's research is focused on developing strategies to replace sugar in starch containing food systems (primarily baked goods) by understanding the effects of non-digestible oligosaccharides and other zero added sugars on the thermal properties of starch and starch-related texture attributes in baked goods.

Binning Wu received her BS in Agronomy from China Agricultural University in 2016 and completed her PhD in the Plant Biology Program at The Pennsylvania State University in 2021. She was a member of Dr. Lavanya Reddivari's lab from 2017 to 2021 to study the anti-inflammatory properties of maize 3-deoxyflavonoids and 3-hydroxyflavonoids against ulcerative colitis. She is now working in Creative Biogene Inc. as a project manager to plan and coordinate ADME and iPSC-related projects.



Tianming Yao obtained his BS in Food Science and Technology from Shanghai Jiao Tong University, China. His undergraduate research was on starch digestibility and property characterization. He joined Dr. Srinivas Janaswamy's group in August 2015 as a master's student with the focus on encapsulation of polyphenols in starch granular networks. In 2017, Tianming continued as a PhD student with Drs. Lindemann and Hamaker with the focus on complex fiber structure and gut microbiome. He was trained in interdisciplinary knowledge in microbiology, carbohydrate chemistry, and multi-omics analyses. He completed his PhD in 2021, and now he works as a postdoctoral researcher in Dr. Stephen Lindemann's lab.

Merve Yildirim received her BS in Food Engineering from Middle East Technical University in Turkey. She completed her MS in the same department, focusing on low-fat products with double emulsions. She joined Dr. Jozef Kokini's laboratory for her PhD studies in 2017. Her research focuses on the nonlinear rheological properties of proteins and biopolymers.

Xinruo "Tina" Zhao received her BS from the Department of Food Science at Purdue University in May 2021. She joined Dr. Bruce Hamaker's lab as a master's student to study how fiber mixtures influence gut microbiome and C. difficile infection.

Rui Zhu completed her BS in Food Science and Engineering from Shanghai Institute of Technology in July 2019. After graduation, she worked in R&D in a confectionery company for two years in China, mainly focused on aerated milk candy products. She joined Dr. Jones' group in August 2021 to pursue her MS. Her current research is about the electrostatic interaction between whey protein isolate and high acyl gellan gum at fairly low concentration.

PhD Postdoctoral Research Associates

Thaisa Cantu Jungles received her BS in Nutrition from the Pontificia Universidade Católica do Paraná (Brazil). She has earned her MS and PhD in Biochemistry from the same university. In 2015, she joined Dr. Hamaker's group as a visiting scholar for a year to conduct part of her PhD research. Her research was centered on the structural characterization of dietary fibers from fruits and their applications in the biological field. In 2018, she rejoined Dr. Hamaker's group as a postdoctoral researcher in the area of dietary fiber fermentation by the gut microbiota. Her current research focuses on the alignment of dietary fibers' chemical and physical structure to promote bacterial groups in the gut related to human health.

Marwa El Hindawy, from Cairo, Egypt, received her PhD from Purdue University in December 2018. She worked with Dr. Hamaker on slowly digestible carbohydrates and their role in activating the gut-brain axis to tackle obesity. During 2021, she worked on a clinical trial to validate the gut-brain axis activation in healthy humans using slowly digestible carbohydrates. In addition, a clinical trial was performed, investigating the attenuating effect of soluble dietary fiber consumption on postprandial blood glucose and insulin.

Shiyu Li received her PhD in Preventive Veterinary Medicine from the Academy of Military Medical Sciences in China, and her MS and BS in Food Science. In 2017, she joined Dr. Lavanya Reddivari's group as a visiting scholar for a year, and is currently working as a postdoctoral research associate in the same lab. Her research focuses on the anti-inflammatory properties of food-based bioactive compounds and the role of gut bacteria.

Jongbin Lim received his PhD in Food Science from Purdue University in 2019. After graduation, he worked in Dr. Hamaker's group as a postdoctoral researcher for two years. He recently started his independent research career as a tenure-track assistant professor in the Department of Food Bioengineering at Jeju National University, South Korea. His group's research focus is to develop new biomaterials from food ingredients for improving physiological responses to obtain health benefits.

Yony Román Ochoa received his BS in Chemistry and MS in Chemical Sciences at University of Antioquia, Colombia. In 2017, he finished his PhD in Sciences–Biochemistry at the Federal University of Paraná (UFPR), Brazil, working on structural characterization, chemical modification, and anticoagulant and antithrombotic activities of polysaccharides. In 2018, he was a postdoctoral researcher in Sciences–Biochemistry in carbohydrates and their application as anticoagulant and antithrombotic regulators. In 2019, he joined Dr. Hamaker's lab as a postdoctoral researcher working on screening and health risk assessment of heavy metals in local staple food-based processed products in the Arequipa Region of Peru. He worked to develop food processes to reduce heavy metal contamination to safe levels, and to evaluate their effects on dietary fiber fermentation by the gut microbiota. Yony moved in 2021 to the University of Georgia.

Oguz Kaan Ozturk completed his BS (2011) and MS (2014) degrees in Food Engineering at Middle East Technical University in Turkey. He also has an MBA (2013) degree from the same university. He received his PhD (2019) in Food Science and Human Nutrition Department from the University of Illinois at Urbana-Champaign, where his research focused on modeling of water transport in food products during drying process. He joined Dr. Hamaker's lab in April 2019 as a postdoctoral research associate and works on projects related to the structure and functionality of proteins and starches. His recent work focuses on plant-based protein food analogues.

K. Vasanth Ragavan obtained his PhD in engineering sciences (Food Technology) from CSIR-Central Food Technological Research Institute, Mysore (India), with the best PhD scholar award. Later, he went on to work as a postdoctoral researcher at the University of Guelph, Canada, for three years, the last of which under the supervision of Professor Martinez for the development of plant-based meat analogs. Ragavan also worked as a sessional lecturer at the University of Guelph and as an assistant professor at Amity University, India teaching bioengineering and food engineering courses. Currently, Ragavan is working as a scientist at CSIR-National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram, India, and as an assistant professor in AcSIR-New Delhi. His research interests include new product development emphasizing sustainable plant-based products and food analysis.

María Julia Spotti earned her BS degree in Biotechnology in 2008 and her PhD in Food Chemistry in 2013, both at the National University of Littoral in Argentina. In 2021, she joined Professor Martinez's group to conduct research focused on structure-function relationship in starch molecules. Before that, she was postdoc research associate at Purdue University (2015-2016) and then associate researcher of the Scientific and Technical Research Council of Argentina (2016-2021). Her research interests focus on the physicochemical study of food colloids and their modifications through enzymatic, physical and chemical processes for improving their functional and nutritional properties, the extraction and characterization of biomolecules from food byproducts and the development of functional foods.

Natalia P. Vidal received her PhD in Food Quality and Safety from the Basque Country University (Spain) in 2015. She then started working as a postdoctoral fellow at Memorial University of Newfoundland (Canada), where she focused on the development of functional foods. In 2019, she joined Dr. Martinez's research group at Guelph University (Canada) and moved to Aarhus University (Denmark) in 2021, where she obtained an AIAS-Marie Skłodowska-Curie CoFund fellowship to develop foundational understanding about the effect of extrusion technology to improve the bioaccessibility and metabolic effects of brown macroalgae bioactive compounds in complex model systems resembling trendy foods.

Whistler Center Staff

Dane Deemer is a hybrid wet-lab and computational biologist focusing on understanding the interactions between microbial populations and host. He is the project manager for Dr. Lindemann's Diet-Microbiome Interactions laboratory, helping students reach research checkpoints and providing bioinformatic expertise. Dane also provides services for industrial clients in areas such as bioinformatics, molecular biology, analytical chemistry, and microbiology. His passion is rooted in automation and big data analysis pipeline creation, and he considers himself a bridge between computer scientists and biologists.

Aminata Diatta received a BS in Natural Sciences in 2002 and a pre-doctorate diploma in Chemistry and Biochemistry of Natural Products in 2006 from Cheikh Anta Diop University, Dakar, Senegal. She joined Dr. Hamaker's group in fall 2015 and successfully defended her MS in May 2018. The title of her thesis was "Using corn zein to improve the quality of gluten-free bread." Aminata worked as a lab assistant in Dr. Hamaker's lab until July 2021.

Angie Gutterman received her bachelor's degree in business administration from Butler University in 1985. She joined the Whistler Center as the center's coordinator in September 2019. Angie is enjoying working with our industrial members, graduate students, and postdocs.

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

Anton Terekhov is proficient in analytical chemistry, molecular biology techniques and analytical instruments such as NMR, GCMS, LCMS and FTIR. Anton has more than 15 years of experience in an interdisciplinary laboratory environment, including the fields of analytical chemistry, microbiology, genetics, geology, and chemical and civil engineering. His main research area is carbohydrate analysis using above-mentioned analytical instruments. He is director of analytical services for the Whistler Center.

Kristin Whitney completed her BS in Food Science and MS in Cereal Science at North Dakota State University. She previously worked in the Department of Plant Sciences at NDSU as a research specialist in the Carbohydrate Chemistry and Wheat Quality group. In August 2021, Kristin joined the Department of Food Science at Purdue University as a senior research associate in Dr. Senay Simsek's group. Kristin assists with research projects related to structure-function relationships of carbohydrates and grain macromolecules. She is responsible for coordinating research projects and sample analyses related to crop utilization, carbohydrate functionality, and functional ingredients in baking.

Our People, Our Projects

Campanella

1. Modeling the Microbial Community in the Gut: The Basics
2. Modeling Inactivation Parameters of Spore Cells Subjected to Cold Plasma and Other Non-Thermal Processes
3. Innovative Green Clean-in-Place Technology with Microbubbles

Hamaker

4. Fabrication and Modification of Dietary Fibers for Targeted Functions in the Gut
5. *In Vitro* Gut Fermentation Studies on Dietary Fibers
6. Specificity of Dietary Fiber Structures in Support of Gut Bacterian
7. Investigations on Slowly Digestible Glycemic Carbohydrates
8. Cellular and Physiological Response of Slowly Digestible Carbohydrates
9. Plant-based Proteins and Zein Viscoelasticity

Jones

10. Protein Fibrous Structures as Physical Simulacrums of High-MW Glutenin
11. Effect of Protein Hydrolysis and Conjugation on Functionality of Corn Protein
12. Effect of Enzymatic Hydrolysis and Extrusion on Bean Flour Functionality
13. Associative Complexes of Dairy Proteins and Gellan Gum

Kokini

14. Applications of Structural Bioinformatics in Understanding Molecular Origins of Gels and Emulsions Made from Pea Protein
15. Relationship of Medium Amplitude Oscillatory Shear (MAOS) Measurements of Soft, Hard, Semolina Dough
16. Development of Cold Extrusion Process for the Functionalization of Pea Protein
17. Investigating the Nonlinear Behavior of Cream Cheese and Sour-Cream
18. Soy Protein Isolate-Based Sensors for the Detection of Food Analytes
19. Development of Relationships Between Protein Secondary Structure and Fundamental LAOS Parameters in Thermoset Protein Gels

Lindemann

20. Bran Arabinoxylan Chemical Structure Effects on Fermentation by Gut Microbiota
21. Species, Particle Size, and Processing Effects on Wheat Bran Fermentation by Gut Microbiota
22. Influence of Resistant Glucan Structure on Fermentation by Gut Microbiota
23. Structure Effects on Competition for Oligosaccharides by Gut Microbiota

Martinez

24. Understanding Structure-Function Relationships of Pectic Polysaccharides from Fruits and Pulses
25. Revalorization of Cold Pressed Oil Seed Cakes through the Removal of Antinutritional Factors
26. Whole Muscle Tissue Engineering using Bio-Polymeric Materials from Plants
27. Upcycling Food and Agricultural Waste into Biodegradable Packaging Materials

Mauer

28. Starch Properties in Different Environments

Narsimhan

29. Volume Fraction Dependence of the Elastic Behavior of Starch Suspensions
30. Effect of Oligosaccharides on Starch Swelling
31. Synergistic Effect of Low Power Ultrasonication on Antimicrobial Peptide Action

Oh

32. Fermentation of Oligosaccharides by Metabolically Engineered Yeast to Alleviate Functional Bowel Disorder Symptoms

Reddivari

33. Anti-Colitic Effects of Anthocyanin Containing Potatoes and the Role of Gut Microbiota
34. Selection of Dietary Fibers for Gut Health based on their Physicochemical Properties
35. Anti-Colitic Effects of Anthocyanin-Pectin Complex

Simsek

36. Structural and Functional Characteristics of Dietary Fiber from Raw and Cooked Dry Beans
37. Evaluation of Production Methods and Groat Type with Effects on Quality Analysis of Oat Beverage
38. Structural Changes in Arabinoxylans during the Breadmaking Process

Yao

39. Molecular Rotor-based Characterization of Biopolymers in Oil/Water Systems including Emulsions
40. OHPP to Improve the Bioavailability and In Vivo Antiviral Efficacy of Niclosamide, a Potential COVID-19 Therapeutic
41. Novel Plant-based Functional Food Ingredients
42. Innovative Food Manufacturing System

Project Summaries

1 Modeling the Microbial Community in the Gut: The Basics

P.I.: O. Campanella

Researchers: Viridiana Tejada Ortigoza (Tecnologico de Monterrey, Mexico); Jenna McClure, PhD student (The Ohio State University)

Collaborators: Bruce Hamaker; Jorge Welti-Chanez (Tecnologico de Monterrey, Mexico); Yael Vodovotz (The Ohio State University)

Objectives: Processes to produce healthy foods using byproducts of the food industry using sustainable technologies (e.g., reactive extrusion). The project is also aiming to understand the nature of microbial communities' interactions and how these might impact the host's health (or disease).

Progress: This project is aimed to provide innovative and sustainable technologies to develop healthy and palatable foods containing valuable ingredients that have positive benefits on the body and mental health.

In collaboration with colleagues at the University of Monterrey, we investigated the use of byproducts of the food industry, notably fibers. In addition to five publications released between 2016 and 2020, a recent study on fecal fermentation of fruit peels has been released in *LWT*. Furthermore, a review article incorporating aspects of engineering to describe the dynamics of microbial species present in the community and their interactions is being completed. The review also provides a molecular view on metabolic reactions where metabolite (e.g., SCFA and vitamins) production and consumption, as well as physical parameters such as diffusion of nutrients through the microbial species or vice versa are considered. Several models involving computational analyses are being reviewed. The main goal of the review is to identify model(s) where general rules are considered, including bulk/convective movement of substrates, diffusion of microorganisms and chemical species, and how diffusion of these species are affected by viscosity. Suitable models will simplify complex information on microbial communities not only for the scientific community but also for industry.

2 Modeling Inactivation Parameters of Spore Cells Subjected to Cold Plasma and Other Non-Thermal Processes

P.I.: O. Campanella

Researcher: Gabriella Mendes Candido de Oliveira, PhD student

Collaborators: F. San Martin; A. Deering (Purdue University, Food Science); Tony Jin (USDA)

Objectives: This project developed experimental and modeling tools associated to a wide range of applications that can assist the food industry to predict, control and improve processing performance to remove potentially harmful microbes, which will ultimately aid in the management of food safety programs.

Progress: The project dealt with alternative food processes such as microwave heating, pulsed electric fields, and cold plasma able to meet those demands. Mathematical modeling was extensively used as a valuable tool for a quantitative assessment of process efficacy that can support food safety decisions considering novel food processing technologies. Publications were released in 2019 and 2020 on the inactivation of pathogens or spores during cold plasma sterilization, pulsed electric field treatments, and microwave treatments of juices. A final publication, "Microbial safety and shelf-life of pulsed electric field processed nutritious juices and their potential for commercial production," was released in the *Journal of Food Processing and Preservation* in 2021, discussing the modeling approaches for pathogen reduction in juices using such non-thermal processing techniques.

3 Innovative Green Clean-in-Place Technology with Microbubbles

P.I.s: O. Campanella, C. Corvalan

Researcher: Nathaniel H. Brown, MS student

Collaborator: J. Lu (University of Massachusetts)

Objective: The general objective of this project was to use microbubbles to clean fouled surfaces of processing equipment.

Progress: A model was developed to further understand the mechanisms of fouling material detachment and movement of microbubbles. Results clearly demonstrated that microbubbles move due to a phenomenon known as the Marangoni effect, which can create "Marangoni" flows promoted by gradients of concentration of surface-active (surfactant) species located in the interface of the microbubbles. The study contributed to a better understanding of self-induced movement of microbubbles generated by these Marangoni flows. The governed transport of surfactants on the bubble interface is also seen in environmental and natural processes, such as the cleaning of oil spills and microorganisms swimming.

4 Fabrication and Modification of Dietary Fibers for Targeted Functions in the Gut

P.I.: B. Hamaker

Researchers: Nusebye Bulut, PhD student; Thaisa Cantu-Jungles, Postdoc

Collaborators: A. Keshavarzian (Rush University Medical School, Chicago)

Objective: Fermentable dietary fibers have the potential to produce positive short chain fatty acid (acetate, propionate, butyrate) changes in the colon and microbiota composition by favoring certain bacteria or bacterial groups. Our interest here is in finding ways to either improve fermentability and function of fibers through use of food technology methods or to fabricate new fiber materials with targeted function.

Progress: Although in 2021 we did less research in this area than in the past, it is still an area of interest and activity for us. Our vision is to fabricate or modify dietary fiber materials that have targeted function in the gut to support certain groups of beneficial bacteria. In other words, to produce prebiotic fiber materials with improved function compared to the natural material. In this regard, we published a paper in 2021, "Boosting the value of insoluble dietary fiber to butyrogenic gut bacteria through food processing," in *Food & Function*. This work showed that a physical modification of cereal bran opened up the cell wall matrix, making it more accessible for fermentation to butyrate-producing bacteria. In a current study, N. Bulut is expanding on previous work, where we showed that a soluble crosslinked arabinoxylan matrix could be made that shifted fermentation toward butyrogenic commensal Clostridia bacteria. Her objective is to fabricate such matrices from a commercially available feruloylated polysaccharide for a beverage application.

5 *In Vitro* Gut Fermentation Studies on Dietary Fibers

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

Researchers: Thaisa Cantu-Jungles, Postdoc; Yony Roman Ochoa, Postdoc; Monica Richmond, MS student; Xinruo Zhao, MS student; Mirian de Campos Costa, Visiting Scholar; Yunus Tuncil, Visiting Faculty

Collaborators: A. Keshavarzian (Rush University Medical School, Chicago); L. Hoagland and A. Rodriguez Sanchez (Department of Horticulture, Purdue); E. Martens (University of Michigan Medical School); O. Campanella (The Ohio State University)

Objective: Fermentable dietary fibers have the potential to produce positive short chain fatty acid (acetate, propionate, butyrate) changes in the colon and microbiota composition by favoring certain bacteria or bacterial groups. Here, our interest is in understanding how various factors affect fiber fermentation, as well as how specific fibers are fermented and affect the gut microbiota. Project #6 describes a further focus on choosing fibers for their support and promotion of specific gut bacteria or groups of bacteria.

Progress: In this year, a study done by Yony Román Ochoa and T. Cantu-Jungles was completed on the effect of heavy metals (lead, arsenic, cadmium, mercury) on gut microbiota growth in the presence of different fiber types that support different bacterial groups. A modest though significant reduction in short chain fatty acids was noted with addition of arsenic and mercury, and a change in the microbiota with mercury in a 24-hour fecal fermentation. In collaboration with L. Hoagland and A. Rodriguez Sanchez, quinoa grown in high cadmium soils produced seeds with intrinsically-incorporated cadmium. In an initial study, it was shown that there was high retention of the cadmium after a simulated upper gastrointestinal tract digestion and with little alteration of fermentation compared to the cadmium-free quinoa. This suggests that may be cadmium bound and not available to the gut bacteria. A further study is planned with Y. Tuncil.

M. Richmond is studying the effect of viscosity on growth of *Bacteroides thetaiotaomicron*, in collaboration with E. Martens and O. Campanella, following the hypothesis that viscous fibers that are slow fermenting (e.g., xanthan gum) have an effect on growth rate of bacteria. The study design shows the effect of different size starch-based substrates (gelatinized amylopectin, maltodextrin, maltose) on growth of *B. theta* in different xanthan gum viscosities. Results will be reported next year.

X. Zhao began her MS studies in fall 2021 and will study the effect of fiber mixtures on the growth of *Clostridium difficile* using an *in vitro* fecal fermentation experimental design. This is in collaboration with A. Keshavazian at Rush Medical School, and has the hypothesis that designed fiber mixtures could be more suppressive of *C. difficile* growth in antibiotic-compromised microbiota than a single fiber. Results will be reported in the next year.

6 Specificity of Dietary Fiber Structures in Support of Gut Bacteria

P.I.s: B. Hamaker, S. Lindenmann

Researchers: Thaisa Cantu-Jungles, Postdoc; Nusebye Bulut, PhD student; Tianming Yao, PhD student

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

Objective: To understand the relationship between dietary fiber chemical and physical structures and their alignment to support specific gut bacteria and bacterial groups, and how gut bacteria community structure affects fiber response. The aim is for predictable outcomes of fibers in individuals.

Progress: In previous work, we reported a fiber that has high specificity, in *in vitro* fecal fermentation, to promote a butyrate-producing species (*Anaerostipes spp.*) and that had consistent response among individuals. An article on this work, "Dietary fiber hierarchical specificity – the missing link for predictable and intense shifts in gut bacterial communities," was published in *mBio* in 2021. N. Bulut and T. Cantu-Jungles are investigating a way to identify fiber structures to support specific beneficial bacteria in the human gut, in other words to support resident gut probiotic bacteria. We have promising results that will be reported next year. In another project, T. Cantu-Jungles has worked toward the mechanistic design of fiber mixtures to support different groups of gut bacteria, each containing recognized health-related bacteria, and with our collaborators at Rush Medical School in a clinical study showed improvement in some important biomarkers in Parkinson's disease patients. Details will be also reported in the next year. Also, two other *in vitro* fecal fermentation studies on targeted-function fibers and fiber mixtures were started in 2021.

T. Yao, who finished his PhD in 2021, did one of his research studies (others were in S. Lindenmann's lab) on how complex carbohydrate structures (i.e., arabinoxylans) are digested and utilized by a common gut bacterium (*Bacteroides cellulosilyticus*). This was a collaboration with E. Martens at University of Michigan. Tianming demonstrated different growth patterns on highly specific arabinoxylans. Residual carbohydrate linkages suggested two different complex arabinoxylan digestion routes on an arabinoxylan containing mixed regions of simple and complex branches versus one with a high number of complex branches. Differential growth speed as well as fiber degradation patterns provided fundamental information how chemical complexities of fiber structure are dealt with by bacteria, and perhaps how fiber structural alignment to bacteria might be achieved for the development of precision prebiotics.

7 Investigations on Slowly Digestible Glycemic Carbohydrates

P.I.: B. Hamaker

Researchers: Jongbin Lim, Postdoc; Anna Hayes, PhD student; Pablo-Torres Aguilar, PhD student; Rosa Lopez, PhD student; Marwa El-Hindawy, Postdoc

Objective: To design slowly digestible glycemic carbohydrates, and to investigate an inhibitor approach, for low glycemic response and with locational digestion into the small intestine ileum to activate the ileal brake and gut-brain axis physiological responses that promote satiety.

Progress: J. Lim published two papers on his work showing that a-amylase inhibition by flavonoids moves starch digestion locationally to the distal small intestine (ileum), and consequently activates the gut-brain axis ("Dietary starch is weight reducing when distally digested in the ileum" in *Carbohydrate Polymers*, and "Structural requirements of flavonoids for selective inhibition of endo-type α-amylase versus exo-type α-glucosidase for inducing slow but complete starch digestion" in *Food Chemistry*, online). In an acute mice study, he showed markedly elevated plasma glucagon-like peptide-1 (GLP-1) levels and in a long-term mice study showed significant change in gene expression of select hypothalamic appetite-

stimulating and -suppressing neuropeptides, and lower food intake and weight gain. Two clinical studies were published showing slowly digestible carbohydrate activation of the ileal brake response, which slows gastric emptying ("Activation of gastrointestinal ileal brake response with dietary slowly digestible carbohydrates, with no observed effect on subjective appetite, in an acute randomized, double-blind, crossover trial" in *European Journal of Nutrition*, online), and showing similar glycemic response for matched refined and whole grain wheat porridges ("Matched whole grain and refined wheat milled products do not differ in glycemic response or gastric emptying in a randomized, crossover trial" in *American Journal of Clinical Nutrition*, online). A clinical study was begun in 2021 to test the hypothesis that a combination of slowly digestible carbohydrate and α-amylase flavonoid inhibitor will activate the gut-brain axis as shown by rise in plasma GLP-1.

R. Lopez began her thesis research studies to develop starches that 1) digest to the ileum, 2) both digest to the ileum and continue to the large intestine as resistant starch, and 3) are wholly resistant starch. These materials will be used in a mice study to understand the interplay in signaling the gut-brain axis through direct carbohydrate activation in the ileum and through fermentation of resistant starch (fiber) in the large intestine.

8 Cellular and Physiological Response of Slowly Digestible Carbohydrates

P.I.s: B. Hamaker, L. Reddivari

Researchers: Anna Hayes, PhD student; Pablo Torres Aguilar, PhD student, Marwa El-Hindawy, Postdoc; Veda Krishnan, Visiting Scholar

Collaborators: B. Nichols (Baylor College of Medicine, Houston); Amy Lin, (A-Star, Singapore)

Objective: To understand the cellular and physiological responses to slowly digestible carbohydrates that might have value in the area of controlled glycemic response, satiety control and metabolic fuel utilization.

Progress: A. Hayes completed her PhD in spring 2021 and reported on a promising finding that slowly digestible carbohydrates, compared to rapidly digestible carbohydrates, seem to promote fat oxidation and improve metabolic flexibility. This was a collaboration with B. Nichols using a series of mice studies done at Baylor College of Medicine, where metabolic cages were used to measure respiratory O_2 and CO_2 to obtain respiratory exchange ratios. The paper will soon be submitted for publication. In a clinical study done by P. Torres-Aguilar, a Kenyan study cohort had significantly different RER than a comparative US cohort, and also slightly improved metabolic flexibility.

V. Krishnan, a Fulbright Visiting Scholar, conducted a series of studies looking at tannic acids as both inhibitors of α-amylase for starch digestion and potential direct stimulators of endoendocrine L-cell GLP-1 secretion, both in L-cell culture and in mice. Positive results were found for activation of the gut-brain axis, and papers will be submitted for publication in 2022.

9 Plant-based Proteins and Zein Viscoelasticity

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

Researchers: Oguz Ozturk, Postdoc; Andres Munoz Salgado, MS student (The Ohio State University)

Objective: To understand whether viscoelastic corn zein networks can be incorporated into commodity plant-based proteins for improvement of texture of meat and cheese analogues.

Progress: O. Ozturk and A. Munoz Salgado showed that conditioned zein can be dispersed as a web-like network into pea protein with improvement in rheological properties. This led to development of formulations (i.e., ingredients with a set of conditions) that mimic the textural profiles of a range of plant-based protein meat and cheese analogues. This work will be described in detail next year and papers for publication are currently being submitted.

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

P.I.: O. Jones

Researchers: Enrico Federici, PhD student; Da Chen, Postdoc

Collaborators: O. Campanella, Gordon Selling (USDA, Agriculture Research Station), B. Hamaker

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

Progress: Previous work in this project demonstrated that extrusion processes allowing significant heat buildup in the extruder barrel promoted viscoelastic

behaviors for zein that resembled wheat gluten when mixed in starch-water composite systems ('doughs'). Such viscoelastic behaviors were superior to fibrous-structured zein prepared by electrospinning when placed in similar starch-water systems. As a final component of this project, zein was heated as a dry powder in ovens to identify whether the heat encountered during extrusion was the predominant driver for desirable viscoelastic behaviors in starch composite systems or if other processes during extrusion were responsible. Findings from the study showed that oven-heat-treatments generated desirable shear-thickening behaviors after its incorporation in starch composite systems, yet the shear-thickening was insufficient to match the properties of a traditional gluten-containing wheat dough and did not replicate the improvements observed for high-temperature extruded zein. These findings were published in *Food Hydrocolloids*.

11 Effect of Protein Hydrolysis and Conjugation on Functionality of Corn Protein

P.I.: O. Jones

Researcher: Wanying He, Visiting Scholar

Objective: Determine the effect of protein glycosylation on function of corn protein.

Progress: Previous work demonstrated our capacity to perform limited hydrolysis of zein from maize and to covalently link short polyglucosamine (chitosan) chains using enzymes to catalyze the reactions. This process improved water solubility, emulsification, and foaming properties of zein without generation of odorous compounds associated with excessive hydrolysis. This work was published in *Food Chemistry*. However, industrial adoption is more likely for a process that minimizes use of costly enzymes or chitosan. Accordingly, a second study determined conditions and ratios necessary to covalently attach uncharged polyglucose (dextran) chains to the partially-hydrolyzed zein to obtain similar functional behaviors. Preliminary tests were also performed to assess the efficiency of hydrolyzing zein by hot-acid treatment.

12 Effect of Enzymatic Hydrolysis and Extrusion on Bean Flour Functionality

P.I.: O. Jones

Researcher: Anael Kimble, MS student

Collaborators: O. Campanella, S. Simsek, M. Martinez

Objective: Determine the effects of extrusion treatments and enzyme-assisted fiber hydrolysis on the rheological and nutritive properties of bean flours.

Progress: This project was initiated in August 2021. A student was recruited for the project and a team was assembled, including several representative from our member companies. Samples of pinto bean flour and various hydrolase enzymes were donated. The student performed initial trials to enzymatically hydrolyze bean flours, and extrusion trials are planned for the coming half-year.

13 Associative Complexes of Dairy Proteins and Gellan Gum

P.I.: O. Jones

Researcher: Rui Zhu, MS student

Objective: Determine the conditions favoring association and colloidal structure development for dairy proteins and gellan gum.

Progress: This project was initiated in August 2021. The student associated with the project has studied the techniques and background literature related to associative complex formation of dairy proteins and charged polysaccharides. Preliminary tests were performed to assess the capacity of high molecular weight charged polysaccharides to form gels via protein association at very low concentrations.

14 Applications of Structural Bioinformatics in Understanding Molecular Origins of Gels and Emulsions Made from Pea Protein

P.I.: J. Kokini

Researchers: Christabel Hartanto, undergraduate student; Harrison Helmick, PhD student

Objectives: This research aims to develop relationships between bioinformatic models of pea protein and give molecular insight on how pea protein forms gels and emulsions.

Progress: This work is part of a USDA grant that aims to develop structure-function relationships of pea protein and how structure can be modified in order to achieve targeted end uses. In this work, a series of homology models have been generated for pea protein, as well as other pulses, from global sources in order to compare the amino acid similarity and differences based on cultivar and growing region. These models are then analyzed for a number of bioinformatic features that are thought to correlate with experimental properties. It has been found that the surface properties of the protein three-dimensional structure correlates well with experimental values like emulsion activity index, surface hydrophobicity, rheological measurements, and zeta potential. This has shown the potential of bioinformatics to predict end-use of proteins based on a model generated from the amino acid sequence of the protein. Future work will involve additional surface analysis and the generation of weighted-average predictive models for pea protein behavior in both gels and emulsions based on the protein primary sequence.

15 Relationship of Medium Amplitude Oscillatory Shear (MAOS) Measurements of Soft, Hard, Semolina Dough

P.I.: J. Kokini

Researcher: Merve Yildirim, PhD student

Objective: This project aims to understand the relationship between the nonlinear behavior of soft, hard, and semolina dough by using medium amplitude oscillatory shear (MAOS) measurements.

Progress: Information on medium amplitude oscillatory shear (MAOS) measurements of food products is limited in the literature. With this research, rheological characteristics of soft, hard and semolina flour dough were characterized by amplitude sweep at various frequencies. SAOS, MAOS, and LAOS regions were detected by harmonic intensities (I2, I3, I5) of stress responses with respect to the fundamental harmonic. Nonlinear characteristics of materials were plotted with respect to amplitude of the deformations and applied frequency (Pipkin plot), providing clear distinction of linear, intrinsic nonlinear and nonlinear regions of dough. The dough samples were optimized with changing water contents so that each dough possessed similar linear properties. Nonlinear properties characterized by MAOS measurements showed that semolina dough had resilient structure that required higher magnitudes of frequencies and amplitude.

16 Development of Cold Extrusion Process for the Functionalization of Pea Protein

P.I.: J. Kokini

Researchers: Sarah Ettestad, undergraduate student; Harrison Helmick, PhD student

Objective: This research develops a process for low temperature functionalization of pea protein involving sub-zero temperatures and shear forces in extrusion and the physicochemical characterization of that extrudate.

Progress: It is well known that proteins denature as the result of heat and other processing techniques, but, as first suggested in 1930, globular protein has also been shown to denature at low temperatures. This interesting phenomenon is driven by the stabilizing entropy on protein three-dimensional structure. In this work, we aim to utilize the intermediate unfolding state of proteins caused by cold denaturation. In this work, we have subjected pea protein to cold temperatures and shear forces and characterized changes in secondary structure, zeta potential, particle size in water, and oil binding capacity. We have shown that cold denaturation does occur in pea protein, and it may lead to more hydrophobic exposure, indicating that cold denatured protein could be used to prepare novel gels and emulsions. This work has been expanded into optimizing both single- and twin-screw extruders to run at temperatures at or below 0°C and observe changes in product texture and physical chemistry.

17 Investigating the Nonlinear Behavior of Cream Cheese and Sour-Cream

P.I.: J. Kokini

Researchers: Anh Minh Le, MS student; Merve Yildirim, PhD student

Objective: This research aims to study the nonlinear rheological behavior of commercial cream cheese brands by analyzing the LAOS results.

Progress: Past studies have found that there are significant differences in the textural properties of cheese made with different fat contents. In this study, two cream cheese samples varying in fat content but with otherwise comparable ingredients were taken from the same manufacturer. Hence, LAOS measurements of these two samples revealed the role that fat plays in the rheological properties of cream cheese. Both cream cheese samples had strain-stiffening and shear thickening behavior when they

enter the nonlinear viscoelasticity region. At small strain amplitude, the whole-fat cream cheese sample had a relatively stronger structure than the low-fat version but decayed faster with increasing amplitude. Deeper data analysis and SEM network quantification are being carried out to study the structural breakdown of these two samples in more details.

18 Soy Protein Isolate-Based Sensors for the Detection of Food Analytes

P.I.: J. Kokini

Researcher: Cindy Mayorga, MS student

Objective: This research aims to create a SERS biosensor platform based on electrospun nanofibers from soy protein isolate (SPI) to detect analytes in food.

Progress: Soy protein isolate (SPI) is one of the most abundant plant proteins in the world that consists of globulin structures. SPI can be used to fabricate electrospun nanofibers if in combination with other polymers. Aspects of these nanofibers depend on solution parameters, such as the viscosity and concentration. In contrast, other parameters during processing, such as voltage and pressure, can directly impact the morphology of the nanofibers. When optimal parameters are identified, well-formed and abundant nanofibers can successfully be obtained. In the second part of this project, the fabricated SPI nanofibers will be decorated using noble metal nanoparticles such as gold or silver to functionalize the nanofibers' surface and serve as a Surface-enhanced Raman spectroscopy (SERS) biodegradable platform for the detection of analytes present in foods.

19 Development of Relationships between Protein Secondary Structure and Fundamental LAOS Parameters in Thermoset Protein Gels

P.I.: J. Kokini

Researcher: Anh Minh Le, MS student

Objectives: This research aims to study the relationship between protein secondary structure profile of pulse proteins and their gelling ability with two different methodologies for interpreting nonlinear rheological data.

Progress: In this work, thermally induced protein gels of pulses will be made. Secondary structure profile of these proteins will be analyzed and the contribution of different bonding interactions which make up the gels will be studied with bond disruptor agents. Gel strength will also be evaluated using creep tests and large amplitude oscillatory sweeps (LAOS). Two methodologies (Sequence of physical processes and Fourier Transform coupled with Chebyshev coefficients) for interpreting LAOS responses will be compared and correlated with the structural properties of the gels studied. The outcome of this work aims to reveal gelling mechanisms of pulses as well as the efficiency of different interpreting methodologies for LAOS data, which eventually helps in formulating new products.

20 Bran Arabinoxylan Chemical Structure Effects on Fermentation by Gut Microbiota

P.I.: S. Lindemann

Researchers: Tianming Yao, PhD student; Adam Quinn, PhD student; Dane Deemer, staff scientist; Laura Libera, undergraduate student

Collaborator: S. Simsek

Objectives: 1) To identify interrelationships between fine fiber structures of dietary fibers and the microbial consortia that most efficiently degrade them, 2) Determine the influence of structural modification of arabinoxylan structure on microbiome responses.

Progress: T. Yao continued his experiments using structural variants of sorghum arabinoxylan (SAX), either from different lines of sorghum (i.e., red vs. white) or enzymatically debranched SAX. Assisted by D. Deemer, T. Yao was able was to sequence and reconstruct member genomes from red and white SAX-consuming consortia and determined that fine carbohydrate structure differences among red and white SAX supported a different degree of microbial diversity over sequential passages. Specifically, red SAX maintained significantly greater diversity than did white SAX over sequential batch cultures, reflected in both the 16S amplicons and genome reconstructions from metagenomes. Interestingly, despite strong inter-individual variation in initial microbiome structures, fecal microbiota from multiple individuals converged as consortia formed, suggesting that individuals retain organisms able to perform these functions (even if not particularly abundant) and standard gut microbiome assays may

simply not sample in sufficient depth to identify them in complex samples. Interestingly, metagenome analysis conducted by T. Yao revealed that different glycoside hydrolase families were selected on red and white SAX. These glycoside hydrolases differed in domain structure (often having different accessory domains) and red SAX maintained a much greater diversity of CAZyme genes and fusions with different domains. Further, T. Yao determined that enzymatic processing of white SAX with arabinofuranosidases in vitro changed the targeting of these molecules to microbiota (with respect to their ability to grow in consortia), both with respect to fermenting microbiome composition and metabolic outputs. Specifically, enzymatic pre-processing with B. ovatus arabinofuranosidases greatly improved the competitiveness of diverse members of genus Bacteroides, including B. ovatus, and changed the utilization pattern of different linkages. Recently, A. Quinn has adapted a similar approach to understanding how similar structural differences might manifest across different wheat species of ancient and modern origin. His work revealed this year that distinct genotypes of wheat, both ancient and modern, differ in arabinoxylan structure. L. Libera and T. Yao continued to investigate the long-term compositional and functional stability of these consortia; if stable, these communities can be shared broadly across the research enterprise to standardize mechanistic studies of arabinoxylan-microbiota interactions.

21 Species, Particle Size, and Processing Effects on Wheat Bran Fermentation by Gut Microbiota

P.I.: S. Lindemann

Researchers: Miguel Alvarez Gonzales, PhD student; Adam Quinn, PhD student

Collaborators: B. Hamaker, S. Simsek

Objectives: 1) Determine the degree to which the fermentation of a bran particle depends upon its size, 2) Identify mechanisms by which particle size might influence the structure and function of gut microbiota, 3) Determine how different mechanisms of mechanical processing might influence microbiota responses to bran particles, and 4) Determine the impact of wheat genotype on microbiome responses.

Progress: M. Alvarez performed experiments to determine to what extent the chemical composition and microbial fermentation of variously-sized bran particles was influenced by the processing method (roller mill, hammer mill, disc mill, cyclone mill, or stone mill) used to reduce the size of those particles. He determined that the arabinoxylan structures isolated from differently sized particles depended upon the milling method used to generate them, especially with respect to degree to which backbone regions were substituted. These chemical composition differences translated into differences in microbial responses – identical fecal microbiota converted particles (even those of the same size) to different metabolic outcomes with respect to short-chain fatty acid (SCFA) production. Interestingly, the outputs of differently milled bran fractions did not exhibit the same trajectories of SCFA production with size. These data strongly suggest that different milling methods expose different resources and create different niches for microbiota. Further, Miguel performed sequential batch transfers using wheat bran as the sole carbon source to identify whether these differences in milling method-induced resource availability compound and select for distinct microbial communities. 16S rRNA gene amplicon sequencing revealed that different microbiota were increasingly responsive to differently milled brans. Further, the relationship between particle size and microbiome response depended upon which processing method was used to reduce particle size. Preliminary scanning electron microscopy analyses of the disturbed particles as well as those colonized by microbiota revealed that the microbial attachment sites are much more abundant in the aleurone layers.

Recently, A. Quinn began a project to identify the extent to which bran structural features of relevance to the microbiome have been altered by selection of production wheat lines over time. To accomplish this, he has performed trial comparison of some ancient and modern wheat lines, revealing differences in arabinoxylan structure and bran fermentation profiles. These encouraging data suggested a larger trial, so, in collaboration with S. Simsek's group at NDSU, multiple field replicates of modern and ancient lines were grown in randomized blocks under the same field conditions. Fermentation of flours from these different lines, digested in vitro to mimic passage through the upper gastrointestinal tract, revealed that distinct genotypes performed differently in fermentations. Further work is ongoing to identify the relationships between genotype, fiber composition and structure, and fermenting microbiota.

22 Influence of Resistant Glucan Structure on Fermentation by Gut Microbiota

P.I.: S. Lindemann

Researchers: Arianna Romero, MS student; Mai Nguyen, MS student; Renee Oles, undergraduate student

Collaborators: B. Hamaker, B. Reuhs

Objectives: 1) To determine whether different glucans select for different microbial composition and diversity and result in different metabolic outcomes *in vitro*, and 2) determine whether these effects also occur *in vivo*.

Progress: A. Romero performed an experiment with three donors in which each donor's microbiota was exposed to 12 different resistant glucan structures in in vitro batch fermentations, measuring pH, gas production, SCFAs, and microbial community structure via 16S rRNA amplicon sequencing. She observed that 1) metabolic outcome from the same resistant glucan varied across donors (e.g., with respect to relative propiogenesis vs. butyrogenesis) and microbial responses. However, across donors some taxa were repeatedly selected by certain dextrin structures, suggesting that there are specificities in interactions among resistant glucans and the organisms which best consume them. Additionally, antagonism/competition among organisms could be observed, in which some organisms are seen to increase in relative abundance at the expense of others. These changes in relative abundance were strongly context-dependent – microbiota from different initial samples did not respond equivalently to the same glucan structures, suggesting either strain specificity in different individuals or interactions with other members governed microbial growth on these substrates. Together, these data suggest that microbial and associated metabolic responses are emergent properties of fiber-microbiome interactions and are not determined either by fiber structure or microbiome composition alone.

Recently, M. Nguyen continued this work using a sequential batch cultivation approach, which revealed that different glucan structures ferment to different metabolic outcomes, even given an identical inoculum. Experiments with each of three donor's fecal microbiota revealed that microbial diversity sustained by each of these carbohydrates relates strongly to structural complexity, and each carbohydrate selected for different microbial populations. These data strongly suggest that increased carbohydrate complexity results in multiplication of niches, and therefore sustainable diversity. Work is now ongoing to determine whether similar influences occur in long-term feeding of mice.

23 Structure Effects on Competition for Oligosaccharides by Gut Microbiota

P.I.: S. Lindemann

Researchers: Jacob Thompson, PhD student; Anurag Pujari, PhD student; Mehdi Marashi, PhD student; Monique Felix, PhD student; Felicia Sackey, MS student

Objectives: 1) To determine the mechanisms by which structural properties of oligosaccharides influence microbial competition for these carbohydrates, 2) to predictively model competition for oligosaccharides given known consumption properties of microbes, 3) to identify signatures of competition for oligosaccharides in complex microbiomes, and 4) to identify oligosaccharide structure-microbiome competition influences on host physiology at high throughput.

Progress: We recently began a program to understand competition for oligosaccharide substrates among microbiota at a predictive level, using a strong focus of carbohydrate chemistry, microbial ecology, computational predictive modeling, and host physiology. We begin this investigation looking at competition along a single structural parameter (branch length) using chicory inulins as model oligosaccharides that vary only in this dimension. This year, we formulated a draft kinetic model that describes degradation of inulins varying in DP according to assumed species parameters. M. Marashi is presently working to extend this model to real-world competition between two isolates derived from our previous inulin sequential batch transfer experiments (Yao, et al, 2020, FEMS Microbiology Ecology), characterizing kinetic responses to different oligosaccharide structures. F. Sackey and M. Felix have successfully evolved strains able to consume larger inulins, and are screening populations of genome-sequenced enterobacteria to determine what genes are important to increased size ranges of inulin consumption. J. Thompson is beginning the process of generating a host-microbiome interactions screening platform, to investigate different combinations of microbiota or metabolites for host impacts. Jacob is working first to define interactions between a common commensal organism, *Faecalibacterium prausnitzii* and its various strains, its metabolites, and epithelial cells. A. Pujari has generated a relatively high-throughput approach to

isolate inulin oligomers of defined DP, which we are working with Dr. Aaron Wright at PNNL to convert into probes for chemical biology analyses.

24 Understanding Structure-Function Relationships of Pectic Polysaccharides from Fruits and Pulses

P.I.: M. Martinez

Researchers: W. Bai, PhD student; Laura Roman, Postdoc; Natalia Prieto, Postdoc; K. Xu, PhD student

Collaborator: M. Guo (Shandong Agricultural University)

Objectives: To understand the yield and molecular structure of pectic polysaccharides from novel sources and their functionality in food systems.

Progress: We have published several papers about the extraction and purification of functional pectins with optimum molecular conformation (Roman, Guo, et al. 2021; Xu, Martinez, et al. 2020). In Roman, Guo, et al. (2021), we showed that purified hawthorn pectins can be obtained through hot acid extraction followed by an enzymatic step for starch removal, which, in turn, results in pectin demethoxylation (most likely acidic demethoxylation). Results also suggest that the linearity of the polyuronide chain, as quantified by the relative molar ratio of rhamnogalacturonan I (RG-I) to homogalacturonan (HG) and the branching degree of RG-I (i.e., amount of galactan, arabinan and/or arabinogalactan side chains), is critical for successful application in emulsion and gel systems. In Xu, Martinez, et al. (2020), we showed that drying at higher temperatures results in the cleavage of HG domains and, therefore, a decrease in molecular weight, which improves the oil absorption capacity and radical scavenging activity of pectins from okra. On the other hand, this occurrence also decreased their water holding capacity, emulsifying stability and thickening behavior. Now we are focusing on investigating the compatibilization of our extracted pectins during self-standing film-making.

25 Revalorization of Cold Pressed Oil Seed Cakes through the Removal of Antinutritional Factors

P.I.: M. Martinez

Researchers: Natalia Prieto, Postdoc; Laura Roman, Postdoc

Collaborator: Senay Simsek

Objectives: The purpose of this research project is to improve the oxidative stability of the lipid fraction in oil seed cold pressed cakes and remove phenolics that decrease the nutritional value of the protein fraction.

Progress: The most abundant oilseed cakes, soybean, rapeseed/canola, and sunflower, and especially those from cold-pressing, contain meaningful amounts of antinutritional polyphenols that limit their potential as plant protein sources. The objective of the first study was to remove polyphenols, and especially sinapic and chrologenic acid derivatives, in canola and sunflower, respectively, without compromising the nutritional and the technological quality of the protein fraction, using pilot-scale extrusion. Extrusion significantly increased the ratio of soluble to insoluble dietary fiber from 0.45 to 0.58 in canola and from 0.19 to 0.31 in sunflower, whereas the opposite was found in soybean (0.52 to 0.36). Canola (67.7 mg GAE/g) and sunflower (58.9 mg GAE/g) exhibited large quantities of polyphenols, which mostly consisted of sinapic and chlorogenic acid derivatives, respectively. Extrusion increased the proportion of free polyphenols and did not significantly reduce the amount of sinapic acid derivatives in canola. On the contrary, extrusion decreased the content of free polyphenols in sunflower by 68 %, respectively. Generally, the extrusion conditions shown in this study resulted in limited protein denaturation and aggregation and a moderate decrease in β-sheet structures (up to 59%), which led to similar liquid holding capacity and enhanced protein solubility. Extrusion notably increased the gastric protein hydrolysis of soybean cake, but it negligibly affected that of canola and sunflower counterparts, possibly due to the counteracting effect of indigestible quinone-protein adducts. Extrusion is a promising technology to reduce polyphenols meaningfully in certain oilseed cakes while retaining or improving protein quality. Furthermore, a lipidomic investigation using Nuclear and Infrared spectroscopy was performed in order to understand the underlying principles of lipid oxidation under hydrothermal challenges. One research paper is in preparation, which will provide mechanistic understanding and a technological basis for the reintegration of oil seed cakes into the food chain.

26 Whole Muscle Tissue Engineering using Bio-Polymeric Materials from Plants

P.I.: M. Martinez

Researchers: Vasanth Ragavan, Postdoc; Laura Roman, Postdoc; Farzaneh Nasrollahzade, PhD student; Shiva Swaraj, MSc student

Collaborator: John Dutcher (University of Guelph, Canada)

Objectives: The purpose of this research project is to advance plant-based meat product and/or technology development in simultaneous protein sourcing/characterization, formulation and processing.

Progress: Promising plant components with fiber-forming and bulking attributes were identified for continuous manufacture of high-quality High Moisture Meat Analogs (HMAA). Several papers are in preparation, and our first paper about hemp protein has just been accepted in Food Hydrocolloids. Five distinct hemp seed protein concentrates (55.9-76.4 % protein, d.b.) produced at industrial scale using dry or wet enrichment technologies were investigated and compared for their functionality and protein molecular properties. Furthermore, non-proteinaceous components were also analyzed to elaborate on the underlying mechanisms for the structuring behavior of hemp protein concentrates during wet extrusion. Although dry fractionation resulted in lower protein concentration, hemp proteins retained their native oligomeric state and their albumin fraction, thus showing higher surface hydrophobicity and solubility, and lower gelation concentration than wet-extracted counterparts. Furthermore, hemp samples were richer in bound polyphenols (>800 mg/100g), presumably phenolic acids, than the control pea sample (573 mg/100g), which resulted in dark colors in wet-extracted samples. Selected HMMA prototypes were prepared and investigated for anisotropy, viscoelasticity, and proton NMR relaxometry. Visual and instrumental anisotropy dramatically increased with the use of hemp protein concentrates, from 0.69 % using Pea, to 0.98 % and 1.41 % using dry- and wet-fractionated fractionated hemp, respectively. Nonetheless, dry-fractionated hemp HMMAs showed the highest proportion of free water in the system (T_{23} proton relaxation time), and an intermediate viscoelasticity between pea and wet-fractionated hemp. Remarkably, SDS-PAGE revealed a significant contribution of disulfide bonds on hemp protein aggregation during processing.

27 Upcycling Food and Agricultural Waste into Biodegradable Packaging Materials

P.I.: M. Martinez

Researchers: Natalia Prieto, Postdoc; Wenqiang Bai, PhD student; Adriana Maribel Aguilar-Torres, PhD student

Objectives: This project aims to understand the supramolecular structure of food and agricultural by-products (e.g. cell wall-rich pomaces and skins), the isolation of valuable polysaccharides, the investigation of their molecular architecture, and their performance as food packaging materials (e.g. in extruded full bio-composites, films and hydrogels).

Progress: The growth in the use of plastics has brought millions of tons of plastic accumulation in the oceans and landfills and it is therefore paramount to design renewable-based biodegradable materials with adequate permeability and mechanical properties. Results from this project has advanced our understanding to develop hydrophobic carbohydrate-based full bio-composites with good mechanical properties. Several key building blocks have been identified with promising potential to close the loop of circularity in a post-fossil fuel economy and several publications are expected to come out in 2022.

28 Starch Properties in Different Environments

P.I.: L. Mauer

Researchers: Travis Woodbury, PhD student; numerous undergraduate students

Objective: To investigate starch properties, including gelatinization and retrogradation, in the presence of a variety of sweeteners, oligosaccharides, and other small molecules, and in environments containing different amounts of water.

Progress: We are investigating the thermal and physicochemical properties of starch in different environments and in the presence of a wide variety of sweeteners, oligosaccharides, and other small molecules to establish relationships between small molecule type and structure, water activity, molecular weight, glass transition temperature, and intermolecular interactions with starch gelatinization, pasting, swelling, and retrogradation traits.

29 Volume Fraction Dependence of the Elastic Behavior of Starch Suspensions

P.I.: G. Narsimhan

Researcher: Prasuna Desam, PhD student

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

Progress: Starches are incorporated in food products for a variety of reasons such as stabilizing, thickening, binding and gelling. Starch occurs as discrete granules. Upon exposure to water, starch granules swell when heated. This results in thickening of starch suspension (known as pasting) due to an increase in volume fraction of swollen granules. Starch pasting results in an increase in its viscosity. Therefore, the texture of a variety of food products such as sauces, puddings, soups, batter mixes etc. are influenced by pasting. The rheology and texture of starch paste obtained by cooking of starch granules are governed by its swelling. It is, therefore, necessary to quantify swelling in order to predict the rheology of starch paste as well as to develop new food formulations. A methodology is developed to predict the storage modulus (G') of starch paste due to granule swelling, given the physical properties of the starch granule and temperature history. This was tested on experimental measurements of granule size distribution and G' for 8% w/w suspensions of waxy maize, normal maize, waxy rice, normal rice, and crosslinked normal maize – all heated to different temperatures (65 to 90 ^{0}C) and holding times (2 to 60 min). Experimental data of storage modulus G^' vs volume fraction ϕ fall onto a master curve when G^' is normalized by its limiting value G_0^'. G_0^' is estimated from a foam rheology theory and measurements of granule interfacial energy. The master curve, coupled with previously developed theories to predict the granule size distribution over time, allows one to semi-empirically predict the storage modulus G' due to swelling with reasonable degree of accuracy.

30 Effect of Oligosaccharides on Starch Swelling

P.I.: G. Narsimhan

Researcher: Prasuna Desam, PhD student

Collaborator: O.G. Jones

Objective: To characterize the effect of oligosaccharide on swelling behavior of starch suspensions.

Progress: Equilibrium swelling of 8 wt% suspension ofwaxy (WMS) and normal (NMS) maize, waxy (WRS) and normal (NRS) rice were characterized when heated to 80 C and with different sucrose concentrations (0 to 30 wt %). The swelling power reached maximum values of 10.5 and 14.5 at sucrose concentration of 5 wt % and 10 wt % for NMS and WRS respectively, increased with sucrose concentration for WMS from 11 to 15.5, and decreased for NRS from 11 to 8.2. The onset temperature of gelatinization increased with sucrose concentration for all starches whereas enthalpy of gelatinization increased for normal maize starches and did not vary significantly for waxy starches. The interaction parameters for three component system of starch, water and sucrose were inferred from static light scattering. The predicted equilibrium swelling for all starches at different sucrose concentrations using Flory-Huggins theory agreed well with experimental data.

31 Synergistic Effect of Low Power Ultrasonication on Antimicrobial Peptide Action

P.I.: G. Narsimhan

Researcher: M. Fitrityanti, PhD student

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

Progress: Ultrasound can be combined with other physical or chemical treatments, such as heat, pressure, and antimicrobial solutions, to increase its effectiveness. Ultrasound treatment could drastically improve decontamination action of antimicrobial peptides by increasing its diffusion in liquid system. The objective of this study is to investigate the synergistic effect of a cylindrical ultrasonic system on antimicrobial effect of a classic antimicrobial peptide Cecropin P1 on inactivation of a Shiga toxin-producing E. coli (STEC), Escherichia coli O157:H7. The inactivation of E. coli in PBS (pH 7.4) were performed using three different treatments: ultrasound (14 kHz, 22 kHz, and 47 kHz), Cecropin P1 (20 µg/ml), and combination of both. The results showed that the combined treatment at higher power level (22 kHz, 8 watts) for 15 minutes of exposure is more efficient, reducing the cell density to six orders of magnitude, compared to individual treatments. Our results on the effect of different frequencies (14, 22, and 47 kHz) also showed that combination of higher frequency (47 kHz, 7.5 W) and Cecropin P1 for one minute of exposure deactivates more cells (up to six orders of magnitude) compared to combined treatment with 14 or 22 KHz ultrasound.

32 Fermentation of Oligosaccharides by Metabolically Engineered Yeast to Alleviate Functional Bowel Disorder Symptoms

P.I.: E. Oh

Researcher: Dahye Lee, PhD student

Collaborator: S. Simsek

Objectives: 1) Engineer enzyme secretion pathways in baker's yeast, 2) Engineer Saccharomyces cerevisiae invertase activity and specificity toward fructan, and 3) Develop a baker's yeast platform for expressing recombinant fructanase.

Progress: Invertase secreted by *S. cerevisiae* insufficiently degrade fructans. Our working hypothesis is that improved enzyme secretion by baker's yeast will enhance undesirable carbohydrate degradation and CO_2 formation, reducing total fermentation time. Combinatorial metabolic approaches have been employed to uncover the underlying structures and relations in genetic networks. We introduced the intracellular β-glucosidase gene (gh1-1) from Neurospora crassa into a S. cerevisiae strain. Second, the yeast strains expressing β-glucosidase were spread on cellobiose agar plates and exposed to 40 W of UV light at 254 nm for 2-8 s. Plates were incubated at 30 °C in the dark after UV-mutagenesis until colonies form. The screening was accomplished via colony size on cellobiose agar plates to select for the best three mutants for further characterization. We will perform genome sequencing to understand the genotype-phenotype relationship. After comparing the genome sequences of wild-type and mutant strains, we will identify causal mutations that significantly affect protein secretion. We expect that the causal mutations can be potential engineering targets to enhance the secretion of recombinant protein of interest in *S. cerevisiae*.

33 Anti-Colitic Effects of Anthocyanin Containing Potatoes and the Role of Gut Microbiota

P.I.: Lavanya Reddivari

Researcher: Shiyu Li, Postdoc

Objectives: 1) To evaluate the anti-inflammatory potential of purple-fleshed potato anthocyanins. 2) To determine the extent to which anti-colitic activity of anthocyanin-containing red/purple-fleshed potatoes depends on the gut bacteria.

Progress: A dextran sodium sulfate (DSS) murine model of colitis was used to evaluate the anti-inflammatory potential of purple-fleshed potato anthocyanins. In a dose-dependent manner, consumption of purple-fleshed potato ameliorated the DSS-induced elevation in gut permeability, oxidative stress, and inflammation. To investigate the relationship between gut microbiota and the anti-inflammatory capacity of anthocyanin-containing potatoes we used DSS-induced colitis mouse with intact and ablated microbiota supplemented with red- and purple-fleshed potatoes. Different anthocyanin-containing potatoes exerted similar anti-inflammatory capacities against DSS-induced colitis. However, neither of these cultivars displayed the protective effects in gut microbiota ablated mice. These results demonstrate that the presence of intestinal microbiota is essential for the anti-colitic activity of anthocyanin-containing potatoes. Given that the gut microbiome changes with the severity of colitis in humans, currently, we are in the process of assessing the anti-colitic activity of anthocyanins during different stages of colitis.

34 Selection of Dietary Fibers for Gut Health based on their Physicochemical Properties

P.I.: L. Reddivari

Collaborators: B. Hamaker and B. Reuhs

Researchers: Edward Moncada, MS Student; Shiyu Li, Postdoc; Kristen Coates, undergraduate student

Objectives: 1) Identify the fiber characteristics that determine the efficacy and tolerance of fiber and 2) determine the role of gut bacterial dysbiosis in fiber tolerance and efficacy.

Progress: We categorized dietary fibers based on structural complexity, solubility, and fermentation rate. We used existing literature to categorize the fibers by high and low structural complexity, while fiber solubility was categorized based upon measurement. The gas production values during *in vitro* fermentation at the 6-hour time-point were used to calculate the fermentation rate of the fibers and categorize them as fast-, medium-, and slow-fermentable fibers. We observed that there's a clear misconception about the relation between solubility and fiber fermentation: raw potato starch, oat bran and high amylose corn starch, which are less soluble fibers, produced a considerable amount of gas. Fermentation rates for these sources was between 0.5 and 1.5mL of gas/h, categorizing them as medium-

fermentable fibers. The total SCFA content and gas production had a positive correlation, whereas a negative correlation was observed between gas production and pH. Bacterial sequencing is presently underway to identify the fiber impact on the fermenting microbiota.

35 Anti-Colitic Effects of Anthocyanin-Pectin Complex

P.I.: Lavanya Reddivari

Researchers: Wenyi Fu, MS student; Shiyu Li, Postdoc

Collaborator: Bruce Hamaker

Objectives: To investigate the anti-colitic effects of anthocyanin-pectin complex.

Progress: The complexation of anthocyanin and pectin improved the stability of anthocyanins against high temperature and high PH. A DSS-induced colitis mouse model was used to investigate the anti-colitic effects of the anthocyanin-pectin complex (APC). Two-week administration of APC orally restored the DSS-induced high gut permeability in mice. In addition to maintaining liver function, the APC significantly increased the total SCFA concentrations in cecal digesta, especially butyric acid. Even though APC did not have significant anti-inflammatory effects, the expression level of IL-17 was significantly reduced compared to the DSS-treated group. Thus, it is worth further investigating the synergistic effect of anthocyanins and pectin in gut microbiota and IL-17 modulation.

36 Structural and Functional Characteristics of Dietary Fiber from Raw and Cooked Dry Beans

P.I.: S. Simsek

Researcher: Ana Magallanes Lopez, PhD student (North Dakota State University)

Collaborator: O. Campanella

Objectives: To characterize the composition and rheological properties of dry beans (pinto and black) SDF extracted from raw and cooked samples.

Progress: Soluble dietary fiber (SDF) was extracted by enzymatic digestion from raw and cooked beans (2 varieties, 3 growing locations). Molecular weight and flow behavior of SDF were investigated. For both bean types, molecular weight distribution was significantly ($P<0.05$) affected by cooking processing. Size-exclusion chromatography suggested the degradation of material with an increase of free fragments and also an increase in the content of HMW fractions. SDF extracted from raw samples possessed lower flow behavior index and a significant degree of shear-thinning behavior. Calcium chloride added during heating and cooling processes acted as a crosslinking agent and prevented collapse of networks during heating, with samples displaying an interaction enhancement around 80°C. The cooking process increased the HMW fraction of the SDF of both dry bean market classes. SDF, especially from raw material, could be used as thickener in food processing due to its shear thinning behavior. The results suggest using SDF, specially from raw material, as an ingredient in foods that undergo heat treatment, such as baked goods.

37 Evaluation of Production Methods and Groat Type with Effects on Quality Analysis of Oat Beverage

P.I.: S. Simsek

Researchers: Brandon Olson, MS student (North Dakota State University); Kristin Whitney, Staff

Collaborator: Teresa Bergholz (Michigan State University)

Objectives: Contributing to the broader goal of efficiently producing high-quality plant-based beverages, this study investigates how certain production methods affect the quality of oat beverages.

Progress: Groats were obtained from Dakota Specialty Milling (Fargo, ND, USA), and rolled groats were purchased from a local grocery store. The three types of groats used include heat treated (Stabilized), non-heat treated (un-stabilized), and rolled groats that were pressed and steamed. Oat milk extractions were done with a (1:4) or (1:6) ratio of grain to water. Extraction was done by dry milling, wet milling or dry milling with α-amylase treatment. After centrifugation, oat milk base was homogenized and characterized by percent solids content, pH, degree Brix, percent yield, and microbial analysis by plate count agar (PCA) after incubation at 30°C for 48 h. Color and appearance of the oat milk bases varied among water ratio and extraction methods. The CFU/ml was significantly ($p<0.05$) less for oat-based samples that underwent dry milling with an α-amylase treatment. The samples that underwent α-amylase treatment needed to be heated to inactivate

the enzyme, destroying microbes during the process and yielding a lower CFU/ml. The dry milling with no α-amylase treatment produced significantly ($p<0.05$) lower yield, as well as significantly ($p<0.05$) lower percent solids. The dissolved solids content of the samples ranged from 0.60-15.65 degrees Brix. Dry milling with an α-amylase treatment yielded a significantly ($p<0.05$) higher degree Brix. Degree brix is detrimental to mouthfeel and is desired in the range of 9–13 degree Brix. The pH of the samples varied slightly among the treatments and were significantly ($p<0.05$) more acidic than the commercial oat milk samples. The differences in pH between commercial oat milk and the oat milk bases are due to the other ingredients in the commercial oat milk. An enzyme treatment will directly impact the product's microbial and physical properties; thus, it is reasonable to believe that an enzyme treatment must be conducted to ensure a high-quality oat beverage.

38 Structural Changes in Arabinoxylans during the Breadmaking Process

P.I.: S. Simsek

Researcher: Yasuyuki Nishitsuji, PhD student (Kyoto University & Nisshin Flour Milling Inc.)

Collaborators: Kenji Nakamura, Katsuyuki Hayakawa (Nisshin Flour Milling Inc.)

Objectives: To elucidate the change in properties and structure of WE-AX and WU-AX during the breadmaking process and to determine whether the changes were due to secondary materials in yeast-containing dough formulations or endogenous components in the flour.

Progress: To understand the role that AX plays in the quality of pan bread, chemical and structural changes of AX were studied during bread preparation and dough fermentation. Flour from three wheat varieties (Bolles, Glenn, and Elgin-ND) was used, and samples were taken at seven stages during the breadmaking process. This study reveals that arabinoxylan in wheat flour changes dramatically during the early stages of the breadmaking process. The solubilization of WU-AX is essential to the functionality of AX in the dough since WE-AX and WU-AX have different effects on dough and baking quality. The cause of solubilization may not be simple and is thought to be determined by a combination of disaggregation and enzymatic degradation. The structure of arabinoxylan, such as degree of substitution and substitution pattern, also changed during the breadmaking process. These changes were especially evident during the mixing and/or fermentation steps. During mixing and the initial stage of fermentation, the increase in the A/X ratio was affected more by the solubilization of AX components having a higher proportion of disubstituted xylose molecules than by the elimination of arabinose molecule by the arabinofuranosidase. Structural changes to AX during fermentation will alter its interaction with other flour polymers such as starch and proteins. As changes in AX structure impact its functionality in wheat flour and doughs, they are expected to play a role in differences in the quality of wheat flours that have similar protein contents. Thus, it may be possible to select for flour with specific AX characteristics that will allow for the best functionality in bread or alter fermentation conditions to alter AX functionality in a way that will improve the quality of the bread.

39 Molecular Rotor-based Characterization of Biopolymers in Oil/Water Systems including Emulsions

P.I.: Yuan Yao

Researcher: Jingfan Chen, PhD student

Objective: To advance the MR-based methodology as a new method to characterize biopolymers.

Progress: When biopolymers are incorporated in the oil/water systems, such as an oil/water two-layer system or an emulsion, the distribution of biopolymer molecules in the oil and aqueous phases and at the oil-water interface affects the properties and performance of the system, such as the stability of emulsion. Since the signals of fluorescence emission of CCVJ, a hydrophilic molecular rotor, are related to the structural characteristics of biopolymers and the polarity of solvent (e.g., oil or water), CCVJ was used to study the oil/water two-layer systems and emulsions. In this project, the biopolymers used were starch octenylsuccinate, phytoglycogen octenylsuccinate, acacia gum, and sodium caseinate. Two manuscripts were prepared in 2021.

40 OHPP to Improve the Bioavailability and In Vivo Antiviral Efficacy of Niclosamide, a Potential COVID-19 Therapeutic

P.I.: Y. Yao (and multiple collaborators)

Researcher: Zhuoran Chen, MS student

Objective: To improve the bioavailability and efficacy of niclosamide.

Progress: Niclosamide is an approved drug to treat tapeworms for both humans and animals. Studies have shown that niclosamide is also a highly potent antiviral compound against several viruses, including SARS-CoV-2, the virus that causes COVID-19. The major disadvantage of niclosamide, however, is its extremely low water solubility that leads to low bioaccessibility and bioavailability, which prohibits its effective use as an antiviral drug. To address this problem, we have used a plant-based drug solubilizer octenylsuccinate hydroxypropyl phytoglycogen (OHPP) to increase the solubility of niclosamide and thus to increase its bioavailability. The results showed that OHPP-formulated niclosamide displayed: (1) substantially increased bioavailability of niclosamide, and (2) substantially increased in vivo antiviral efficacy against SARS-CoV-2.

41 Novel Plant-based Functional Food Ingredients

P.I.: Y. Yao

Researcher: Zhuoran Chen, MS student

Objective: To explore novel functional food ingredients from plant sources.

Progress: We have been exploring novel functional ingredients from crops. Phytoglycogen is an example of these ingredients with its capability to solubilize poorly water-soluble ingredients such as quercetin, curcumin, and lutein. Recently, we are making further progress in this research area with a focus on plant-based food ingredients. In this research, we used commercial food ingredients such as modified starch as comparisons for evaluating the functionalities. Preliminary data showed comparable or better performances of natural plant-based ingredients as compared with commercial ingredients. Based on these results, we plan to optimize the preparation of these plant-based food ingredients and study the performances of these ingredients in different food systems.

42 Innovative Food Manufacturing System

P.I.: Y. Yao

Researcher: Zhuoran Chen, MS student

Objective: To create a new food manufacturing system, using plant-based proteins as models.

Progress: This is a new initiative under the scope of "Advanced Manufacturing of Food (AMoF)", a research platform for designing the next generation of technologies to enhance food supplies, reduce food waste, and address global challenges of malnutrition and hunger. There are four primary elements in AMoF:

- Integration of artificial intelligence and machine learning in food manufacturing systems,
- Novel food design and processing to achieve precision nutrition,
- Advanced manufacturing including new bioprocessing, green processing, and other novel manufacturing systems to provide high-quality foods with reduced uses of energy and water,
- Reduced supply chain burden and food waste through developing and using new food ingredients with high stability for long-term storage and long-distance transportation.

Under the scope of AMoF, this project is to create a prototype of the new food manufacturing system using plant-based proteins as models.

Publications and Other Scholarly Activities

A. Papers, Books, and Chapters Published

BeMiller, J.N.

1. **BeMiller, J.N.** (2021). The effects of hydrocolloids on normal and waxy maize starches crosslinked with epichlorohydrin. *Food Hydrocolloids, 112,* 106260.

Campanella, O.H.

2. **Campanella, O.H., Federici, E.,** Selling, G.W., & **Jones, O.G.** (2021). Thermal treatment of dry zein to improve rheological properties in gluten-free dough. *Food Hydrocolloids, 115,* 106629-106629.

3. **Chen, D., Jones, O.G.,** & **Campanella, O.H.** (2021). Plant protein-based fibers: Fabrication, characterization, and potential food applications. *Critical Reviews in Food Science and Nutrition, 1-25.*

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See paper in Ferruzzi (N'khata et al.)

Jones, O.G.

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Reddivari, L.

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Reuhs, B.L.

See paper in Campanella (Fei et al.)

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Simsek, S

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123. **Simsek, S.,** Snelling, J., Malekmohammadi, S., & Bergholz, T.M. (2021). Vacuum steam treatment of soft wheat: Quality and reduction of Escherichia coli O121 and Salmonella Enteritidis PT30. *Cereal Chemistry, 98*, 123–134.

124. Tucker, J.R., Legge, W.G., Maiti, S., Hiebert, C.W., **Simsek, S.,** Yao, Z., Xu, W., Badea, A., Fernando, W.G.D. (2021). Transcriptome alterations of an in vitro-selected, moderately resistant, two-row malting barley in response to 3ADON, 15ADON, and NIV chemotypes of fusarium graminearum. *Frontier in Plant Science, 12,* 1567.

125. Vargas, M.C., & **Simsek, S.** (2021).. *Foods, 10,* 2054.

126. Vatansever, S., **Whitney, K.,** Ohm, J.B., **Simsek, S.,** & Hall, C. (2021). Physicochemical and multi-scale structural alterations of pea starch induced by supercritical carbon dioxide + ethanol extraction. *Food Chemistry, 344,* 128699.

127. Vegi, A., Stebbins, B.R., Ransom, J.K., & **Simsek, S.** (2021). Impact of glyphosate applied preharvest on oat kernel quality. *Cereal Chemistry, 98,* 866–877.

See paper in Hamaker (Fang et al.)

Yao, Y.

128. Hernandez-Franco, J.F., Mosley, Y.C., Franco, J., Ragland, D., **Yao, Y.,** & HogenEsch, H. (2021). Effective and safe stimulation of humoral and cell-mediated immunity by intradermal immunization with a cyclic dinucleotide/nanoparticle combination adjuvant. *The Journal of Immunology, 206,* 700-711.

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

January

Hamaker, B.R. Digestive fate of resistant starch and the physiological effects of its fermentation in the colon. ICC.

Martinez, M.M. Nutritional improvement of foods through extrusion. Seminar organized by Transcolab through Interreg funds. Braganca, Portugal.

Yao, Y. New approaches for starch modification. Whistler Center for Carbohydrate Research Webinar Series, West Lafayette, IN

February

Lindemann, S.R. The one you feed: identifying specific interactions of dietary fibers and gut Microbiota. Department of Food Science and Technology, University of California-Davis.

Martinez, M.M. Good carbs, bad carbs: gaps and opportunities of polysaccharides in a sustainable and convenient world. Seminar series at the Department of Health Sciences and Technology at ETH – Zurich.

Martinez, M.M. Structuring plant carbohydrates – prospective ingredients and molecular mechanisms. innFOOD Conference 2021 organized by iFOOD Center for Innovative Food Research, University of Aarhus.

March

Hamaker, B.R. Path towards predictable microbiota outcomes for fibre prebiotics. Beneficial Microbes Conference.

Helmick, H., Kokini, J.L. Fundamentals of Bioinformatics for the baker. Virtual American Bakery Association Convention.

Lindemann, S.R. The one you feed: identifying specific interactions of dietary fiber structures and the gut microbiota that ferment them. Gut Microbiome Webinar Series, Institute for the Advancement of Food and Nutrition Sciences.

Lindemann, S.R. Fine fiber structure-microbe interactions: implications for gut ecology and precision and population-scale nutrition. Future of Microbiome Virtual Conference, Global Prebiotic Association.

Lindemann, S.R. Stochasticity and determinism in fiber targeting to gut microbiota. Nestlé.

Magallanes-Lopez, A., Whitney, K., Simsek, S. Solvent retention capacity: supplemental solvents for evaluation of gluten quality. 16th ICC Cereal and Bread Congress.

Nasrollahzadeh, F., Chang, B.P., Shiva Swaraj, V.J., Mekonnen, T., Brown, L., Dutcher, J.R., **Martinez, M.M.** Comprehensive characterization of novel plant protein concentrates after thermomechanical treatment. Meat Analogues Conference, Wageningen University and Research (WUR).

Reddivari, L. Nutrient bioavailability – phytonutrient and beyond, Anti-colitic effects of flavonoids: Role of gut bacteria, W4002 Multi State Meeting.

Reddivari, L. Near-isogenic lines to unravel the whole food-health complexity. Department of Horticulture and Landscape Architecture. Purdue University.

Whitney, K., Magallanes-Lopez, A., Simsek, S. Solvent retention capacity utilizing supplementary solvents for hard red spring wheat quality evaluation. 16th ICC Cereal and Bread Congress.

April

Dent, T., **Campanella, O.H.,** Maleky, F. Effectiveness of commercial bitter maskers at reducing bitterness of hydrolyzed soy protein. Edward F. Hayes Graduate Research Forum.

Ferruzzi M.G. Leveraging genetic variation of phytochemical bioavailability from fruits and vegetable as a tool to improve delivery of health benefits. Italian National Research Council, Institute for the Science of Food Production (ISPA).

Hamaker, B.R. Concept of personalized nutrition related to carbohydrates. Whistler Center for Carbohydrate Research Webinar Series, West Lafayette, IN

Janahar, J.J., Balasubramaniam, B., Jimenez-Flores, R., **Campanella, O.H.** Rheological characterization of protein solutions under pressure, shear, temperature and interactions. 2021 CFAES Annual Research Conference.

Lindemann, S.R. Probiotics 101. McCormick & Co.

Martinez, M.M. Mesoscale structuring of gluten-free bread with starch. 72 Starch Convention of the Association of Cereal Research Association in cooperation with the Max Rubner Institute. Detmold, Germany.

Martinez, M.M. Starch nutritional quality: Beyond intraluminal digestion in response to current trends. 72 Starch Convention of the Association of Cereal Research Association in cooperation with the Max Rubner Institute. Detmold, Germany.

Martinez, M.M. Shear-induced molecular fragmentation decreases the bioaccessibility of fully gelatinized starch and its gelling capacity. 72 Starch Convention of the Association of Cereal Research Association in cooperation with the Max Rubner Institute. Detmold, Germany.

Martinez, M.M. Starch nutritional quality. Current gaps and opportunities in the world of convenience. Whistler Center for Carbohydrate Research Webinar Series, West Lafayette, IN.

Oh, E.J. Engineering yeast strains for producing food ingredients and value-added chemicals. KSBB Spring Meeting and International Symposium, The Korean Society for Biotechnology and Bioengineering (KSBB).

Reddivari, L. Anti-colitic effects of anthocyanins: Role of gut bacteria. American Chemical Society Conference.

May

Helmick, H., Bhunia, A., Liceaga. A., **Kokini, J.L.** Functionalization of pea protein through cold denaturation: from bioinformatic modeling to the food industry. Purdue University Office of Interdisciplinary Graduate Programs (OIGP) Spring Reception.

Martinez, M.M. Quick viscosity indicators to assess the quality of cereals and grains. AETC Training Plan. Spain.

Park, C., **Campanella, O.H.,** Maleky, F. The rheological properties of oleocolloid and networks. American Oil Chemists' Society.

June

Fu, W., Reddivari, L. Complexation with polysaccharides enhanced polyphenol gastrointestinal stability and activity. American Society for Nutrition.

Li, S., Reddivari, L. Improvement of gut barrier function by potato anthocyanins is dependent on gut microbiota, American Society for Nutrition.

Martinez, M.M. Baked goods rich in health promoting cell walls: opportunities and challenges for fruit and vegetable by-products. BIET21.

Oh, E.J. Engineering yeast strains for producing food ingredients and value-added chemicals. Whistler Center for Carbohydrate Research. West Lafayette, IN

July

Erturk, M.Y., Kokini, J.L. SAOS and MAOS (Small and Medium Amplitude Oscillatory Shear) rheological characteristics of food hydrocolloids. Institute of Food Technologists Annual Meeting.

Erturk, M.Y., Kokini, J.L. Determination of MAOS (Medium Amplitude Oscillatory Shear) region of hard wheat, soft wheat and semolina dough. Institute of Food Technologists Annual Meeting.

Helmick, H., Kokini, J.L. Bioinformatic modeling of cold denaturation in pea protein. Institute of Food Technologists Annual Meeting.

Helmick, H., Bhunia, A., Liceaga, A., **Kokini, J.L.** Bioinformatic modeling of cold denaturation in pea protein. Institute of Food Technologists Annual Meeting.

Helmick, H., Bhunia, A., Liceaga, A., **Kokini, J.L.** Cold denaturation of proteins: Where bioinformatics meets thermodynamics to offer a mechanistic understanding – pea protein as a case study. Institute of Food Technologists Annual Meeting.

Janahar, J.J., Balasubramaniam, B., Jimenez-Flores, R., **Campanella, O.H.** Rheological characterization of protein solutions under pressure, shear, temperature and interactions. Institute of Food Technologists Annual Meeting.

Jones, O.G., Federici, E., Selling, G.W., **Campanella, O.H., Hamaker, B.R.** Impacts of protein physical structure on the properties of polysaccharide-rich composites: zein in gluten-free doughs. Institute of Food Technologists Annual Meeting.

Jones, O.G. The effect of protein aggregation on interactions with polysaccharides. Whistler Center for Carbohydrate Research Webinar Series, West Lafayette, IN

Martinez, M.M. Nutritional and extra-nutritional compounds in fruit and vegetable waste and their potential for use in dietary supplements. 2021 ASAS-CSAS-SSASAS Annual Meeting & Trade Show.

Mayorga, C., Kokini, J.L. Fabrication of soy protein isolate (SPI) electrospun nanofibers for a biodegradable SERS platform to detect toxic analytes. Institute of Food Technologists Annual Meeting.

September

Ferruzzi, M.G. Understanding plant genetic influences on bioavailability of phenolics. 14th International Congress on Polyphenol Applications.

Ferruzzi, M.G. Polyphenols as prebiotics? Can their interactions modify carbohydrate digestion? 11th Annual Probiotics, Prebiotics and Botanicals. Rome.

Ferruzzi, M.G. Food-to-food fortification for provitamin A carotenoids: Progress, synergies and interactions with other fortification strategies. 24th Biennial International Congress South African Association for Food Science and Technology (SAAFoST).

Hamaker, B.R. Food-to-food fortification for local tastes and market-led nutrition. 24th Biennial International Congress South African Association for Food Science and Technology (SAAFoST).

Hamaker, B.R., Hub-and-Spoke Food Innovation System for urban and rural food processing and nutrition. Africa Post-harvest Congress and Exhibition (AAPHCE).

Martinez, M.M. Importance of starch structure on its technological and nutritional quality. I Euro-American Congress of Food Processes and Products (CEAPA).

Martinez, M.M. Structuring plant-based whole muscle cut analogues using extrusion and less-refined, protein-rich colloids. GFI Webinar Series.

Vidal, N.P., Bai, W., Geng, M., **Martinez, M.M.** Organocatalytic acetylation of pea starch. First Circul-a-bility Conference 2021.

October

BeMiller, J.N. The effects of hydrocolloids on starch behavior. 2021 Starch Round Table.

Dent, T., **Campanella, O.H.,** Maleky, F. Hydrolysis of soy and chickpea proteins by alcalase and flavourzyme lead to hydrogen bonding mediated aggregation of hydrolysates. AOCS Plant Protein Science and Technology Forum.

Erturk, M., Kokini, J.L. (2021). Determination of MAOS (Medium Amplitude Oscillatory Shear) region of hard wheat, soft wheat and semolina dough. 92nd Annual Meeting of the Society of Rheology.

Erturk, M., Kokini, J.L. (2021). Comparison of sequence of physical processes (SPP) and fourier transform coupled with chebyshev polynomials (FTC) methods to interpret large amplitude oscillatory shear (laos) response of viscoelastic doughs and viscous pectin solution. 92nd Annual Meeting of the Society of Rheology.

Hamaker, B.R. What are the best dietary components for targeting the microbiome to improve human health? Agriculture & Health Summit, University of Nebraska.

Hamaker, B.R. Prebiotics, what the science says and offers. Supply Side West, International Probiotics Association, Las Vegas, NV.

Nasrollahzadeh, F., Roman, L., Shiva Swaraj, V.J., **Ragavan, K.V., Vidal, N.P.,** Dutcher, J.R., **Martinez, M.M.** Highly fribillar whole cut meat analogs from different hemp protein concentrates (*Cannabis sativa* L.). 3rd Emerging Meat Alternatives Conference (EMAC).

Nasrollahzadeh, F., Roman, L., Shiva Swaraj, V.J., **Ragavan, K.V.,** Trinh, B. M., Mekonnen, T., Dutcher, J.R., **Martinez, M.M.** Role of non-protein components on plant-protein concentrate processability into anisotropic food systems. 3rd Emerging Meat Alternatives Conference (EMAC).

November

Hamaker, B.R. Lifting the veil on how food is made. Sound Bites, Eat Well Global.

Hamaker, B.R. Role of cereals, dietary fibers and carbohydrates in maintaining gut homeostasis. Cereals & Grains 2021.

Helmick, H., Hartanto, C. Bhunia, A., Liceaga, A., **Kokini, J.L.** Understanding cold denaturation through bioinformatics in pea protein. Cereals & Grains 21.

Jones, O.G. Structuring and modifications to improve function of zein within food materials. International Conference on Frontier Technology of Food Science.

Lindemann, S.R. Prebiotics, probiotics, synbiotics, and dietary fibers: where are we in our quest to predictably shape the gut microbiome for health? Whistler Center for Carbohydrate Research Webinar Series, West Lafayette, IN.

Maddakandage Dona, J., Simsek, S. Variation in content and spacial distribution of non-starch polysaccharides in ancient and modern wheat species. Cereals & Grains 21.

Magallanes-Lopez, A., Campanella, O.H., Simsek, S. Structural and functional characteristics of dietary fiber from raw and cooked dry beans. Cereals & Grains 21.

Mayorga, C., Kokini, J.L. Development of a SERS biodegradable platform using electrospun soy protein isolate fibers for the detection of food analytes. AIChE Virtual Meeting.

Narsimhan, V., Li, J., Desam, G.P., **Narsimhan, G.** Prediction of swelling and pasting behavior of starch suspensions. AIChE Annual Meeting.

Olson, B., **Magallanes-Lopez, A., Whitney, K., Simsek, S.** Evaluation of production methods and groat type with effects on quality analysis of oat beverage. Cereals & Grains 21.

Simsek, S. Whole grain for thought: Where are we now and where are we headed in whole grains research? Dietary Fiber in Ancient Grains: From Grain to Bread. CIMMYT-CGIAR webinar to celebrate International Whole Grains Day, Texcoco, Mexico.

Vidal, N.P., Roman, L., Swaraj, S., **Ragavan, K.V., Simsek, S., Martinez, M.M.** High shear intermediate-temperature extrusion to improve the protein quality of cold-pressed oilseed cakes. Cereals & Grains 21.

Whitney, K., Alava-Vargas, M., **Simsek, S.** Stone milling: characterization of flour quality. Cereals & Grains 21.

December

Hamaker, B.R. Food carbohydrates designed for precision health outcomes. Seminar, The Ohio State University.

Hamaker, B.R. How starch could be a weight-reducing carbohydrate. SLACA, Brazil.

Hamaker, B.R. The idea of precision nutrition and food carbohydrates. Whistler Center for Carbohydrate Research Webinar Series, West Lafayette, IN

Lindemann, S.R. Fine carbohydrate structure deterministically maintains diversity in microbial communities. Army Research Office.

Reddivari, L. Harnessing the anti-inflammatory potential of anthocyanin-containing foods: Role of gut bacteria. Interdepartmental Nutrition Program, Purdue University.

C. Graduate Degrees Awarded

Spring 2021

1. Emmanuel Ayua, PhD**,** Studies on extrusion processing of instant porridge flours for African processor optimization, acceptance, marketability for consumers, and improvement in in vitro fecal fiber fermentation.
2. Jingfan Chen, PhD, Exploring functional carbohydrate polymers: their interactions with small-molecule fluorescent probe (molecular rotor) and active compounds.
3. Enrico Federici, PhD, Physical and chemical treatment of zein to improve gluten-free bread quality.
4. Anna Hayes, PhD, *In vitro* and *in vivo* investigations of carbohydrates with different digestibilities for improved satiety and metabolic health.
5. Arianna Romero Marcia, MS, Effect of glucan chemical structure on gut microbiota composition and function.
6. Binning Wu, PhD, Maize flavonoid rich diet ameliorates experimental colitis – role of gut microbiota.

Summer 2021

7. Micaela Hayes, PhD, Influence of spinach genotype and processing method on chlorophyll and carotenoid bioaccessibility in the upper and lower gastrointestinal tract.
8. Zulfioquar Mohamedshah, MS, Comparative assessment of phenolic bioaccessibility and bioavailability from 100% juice and whole fruit – a preclinical approach.

Fall 2021

9. Wenyi "Chloe" Fu, MS, Anthocyanins and polysaccharides interaction on gut barrier function.
10. Sarah Pitts, MS, The impact of dietary fiber and sucrose alternatives on texture perception of cookies.
11. Tianming Yao, PhD, Fine arabinoxylan structure impacts on human gut microbiota composition and function: potential substrates for management of microbiome composition and health benefit.

D. Recognitions, Awards, and Honors

Miguel Alvarez Gonzales
Kirleis Graduate Student Award

Bruce Hamaker
Lowell S. Hardin Award for Excellence in International Agriculture
Purdue University, College of Agriculture

Harrison Helmick
Cereals and Grains (AACCI) Poster Competition, first place, November 2021
Cereals and Grains Student Association, Chair
Institute of Food Technologist: Midwest Area Meeting/College Bowl Chair
Cereals and Grains Student Association, Chair
Purdue Data Mine; Contributor
Cereals and Grains Association Best Student Research, first place: Pulse Division

Steve Lindemann
Promoted to rank of associate professor

Ana Magallanes- López
Young scientist award for best poster presentation, 16th ICC Cereal and Bread Congress

Mario M. Martinez
Sapere Aude Research Leader, Independent Research Fund Denmark (DFF)
https://dff.dk/en/grants/research-leaders-2021/researchleader-21?set_language=en
The Nils Foss Talent Prize
https://www.fossanalytics.com/en/News-Articles/Newsforum/Global/2021/celebrating-entrepreneurship
Ontario Early Researcher Award (ERA)

Cindy Mayorga
Purdue University Food Science Graduate Student Association, Vice President
Kirleis Graduate Student Award

Lisa Mauer
2021 IFT Fellow, Institute of Food Technologists

Natalia Prieto
Aarhus Institute of Advanced Studies
AIAS COFUND Marie Skłodowska-Curie Fellowship
Welcome to seven new fellows (au.dk)

Eun Joong Oh
Outstanding Graduate Educator Award, Department of Food Science, Purdue University.

Vasanth Ragavan
Promoted to permanent scientist at CSIR-NIIST.

Lavanya Reddivari
Outstanding Undergraduate Counselor Award, Department of Food Science, Purdue University.

Laura Roman
L'Oreál, UNESCO and the Royal Danish Academy of Sciences and Letters: For Women in Science Award
Laura Roman Rivas awarded as role model for female researchers

Senay Simsek
2021 Dean's Chair in Food Science, Purdue University, Board of Trustees

Travis Woodbury
PMCA Student Outreach Program Scholarship to attend the Professional Manufacturing Confectioners Association

Yuan Yao
Showalter Faculty Scholar

Merve Yildirim
Society of Rheology Student Travel Grant
Bilsland Dissertation Fellowship
Phi Tau Sigma, Hoosier Chapter President
Phi Tau Sigma, Student Relations Representative

E. Special Events

Whistler Center Short Course, October 5, 2021

As is our tradition, the course is designed to provide one day on carbohydrate fundamentals followed by two days of advanced special topic sessions. Due to the COVID-19 pandemic, the Short Course was held online again in 2021. We convened for a full day on October 5, and our advanced courses were held on October 14 and 19. All sessions were recorded so that our members could visit our website to view the recordings. This enabled them an opportunity to attend all offerings. For individuals subscribing to our Educational Package, the Short Course recordings were available for one month.

- Starch granule structure and properties, S. Simsek
- Introduction to carbohydrates: Basic concepts - monosaccharides, oligosaccharides, and polysaccharides, Y. Yao
- Modifications of starch and other polysaccharides, Y. Yao
- Basic principles of Rheology and viscoelasticity and applications in the world of Cereal Products, J. Kokini
- Polyols and high-intensity sweeteners, Y. Yao
- Carbohydrate nutrition and labeling, B. Hamaker

October 14, 2021

- Hydrocolloids and functionality (Part I & II), J. Keller
- Sugar reduction/replacement with oligosaccharides, T. Woodbury
- Phase stability of polysaccharide mixtures, O. Jones
- Enhanced processing and end product quality through the utilization of functional carbohydrates, S. Simsek
- Predictive modeling of multiphase systems, G. Narsimhan

October 19, 2021

- Understanding microbiome data in dietary fiber studies, S. Lindemann
- Formulating plant-based foods: structure-function relationships of complex plant tissues, M. Martinez
- Microbial fermentation to reduce undesirable carbohydrates, E. Oh
- Complex carbohydrate structure analysis (non-starch), B. Reuhs
- Advances in chemical and physical modifications of starch, S. Simsek and Y. Yao
- Dietary fibers and their use as prebiotics, B. Hamaker

2021 Belfort Lecture

2021 Belfort Lecturer

Dr. Peter Ulvskov

Department of Plant and Environmental Sciences
University of Copenhagen, Denmark

The Belfort Lectures were established and endowed by Dr. Anne D. Belfort in memory of her late husband, Dr. Alan M. Belfort, who was awarded a PhD degree from Purdue University in carbohydrate chemistry in 1960. Support for the Belfort Lectures was generously continued by their daughter Anne E. Belfort. Persons honored by being chosen to give a Belfort Lecture are scientists who have made outstanding contributions to glycoscience.

Our 2021 Belfort Lecturer, Dr. Peter Ulvskov, is a professor of plant biology. He was educated at the Royal Veterinary and Agricultural University in Denmark. It has since been merged into Copenhagen University, where he is now employed. He did his PhD while employed at the Danish Sugar Factories (now Nordic Sugar). He has collaborated extensively with both Nordic Sugar and the Danish enzyme provider Novozymes, reflecting a genuine interest in applied aspects of fundamental research. He spent his postdoc years at Stanford University in the laboratory of Peter M. Ray. The biology of the plant cell wall is his core area of research interest comprising several sub-areas: complex polysaccharide biosynthesis, biophysics of cell walls, and evolution of early plants leading to terrestrialisation. Applied interests include the use of transgenic plants in breeding and the prospect of learning from plants how to build composite biomaterials.

Dr. Ulvskov's research is mainly focused on the following areas:

- Plant cell wall polysaccharide biological significance, biosynthesis, evolution, functionality, assembly and industrial applications thereof.
- Bioinformatics, gene discovery and characterization of genes encoding enzymes that take part in cell wall metabolism.
- Valuable traits in higher plants that depend on cell wall polysaccharides.
- Transgenic plants in breeding.

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