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## DIRECTOR'S STATEMENT – 2001

The President of Purdue University, Dr. Martin Jischke, has engaged the university community in preparing a strategic plan. Since its beginning, the Whistler Center has had a strategic plan, but the President's emphasis has prompted us to take a fresh look at it. In so doing, we reconsidered our Mission and Vision statements and adopted the following objectives to direct us to the next level of excellence:

- 1. Achieving and sustaining preeminence in research/discovery related to practical uses of carbohydrates, especially in foods.**
- 2. Attaining and preserving superior quality and value in graduate and post-doctoral education in areas of research focus.**
- 3. Addressing needs of Sustaining Member companies as partners in research program planning and fulfillment.**

The highlight of the year has to be the addition of Bradley L. Reuhs to the Center's faculty. Dr. Reuhs, a structural polysaccharide chemist, came to the Whistler Center from the Complex Carbohydrate Research Center and the Department of Biochemistry and Molecular Biology of the University of Georgia, where he was most recently an Assistant Research Biochemist. His addition to our faculty provides expertise in structures of the polysaccharide components of plants and bacteria.

But during the year, we lost Rick Millane and Paul Cornillon, both of whom returned to the countries of their birth. Rick is now at the University of Canterbury in New Zealand and Paul is with the Danone company in France. We hope to find replacements for them soon, so that we will continue to be a cohesive unit with the core competencies required to fulfill our mission and vision.

Following a trend that has existed since the beginning of the Center, this, the 2001, report is the largest ever. As the report will reveal, the Center continued its upward and onward progress, not just in doing more, or even in doing what we have been doing better, but by being responsive to challenges and needs and by expanding our understandings of properties and functionalities of carbohydrates. (And what is reported, as always, is only a portion of what has been done, because some projects are confidential.) That the Center has been able to progress during a time of declining memberships is a tribute to terrific faculty and high-quality students. We certainly thank our current Sustaining and Associate Members who provide the unrestricted funds that give us the flexibility and leverage that allows us to take advantage of opportunities.

At the annual meeting of our Industrial Advisory Board, I discussed our research philosophy, using the book Pasteur's Quadrant by Donald Stokes as the basis for the discussion. I pointed out that we think in terms of research that is intellectually challenging and fundamental while having practical, commercial ramifications, and we encourage those approaching us to think in the same way. WCCR research is inspired, driven, and justified by both a desire for knowledge and an intention of serving the carbohydrate-producing and -utilizing industries. To do this, we combine disciplines to meet our basic mission of fundamental research on carbohydrates related to their practical applications, especially but not exclusively, in foods. It's exciting.

James N. BeMiller

## **SUMMARY OF MAJOR RESEARCH ACCOMPLISHMENTS - 2001**

### **Starches and Cereals:**

In Dr. Hamaker's laboratory, studies were begun on slowly digesting starches with the aim of finding new approaches to make them (Project 26). Starch from cooked sorghum flours is known to be slowly digesting and *in vitro* work showed that this characteristic is related to its comparably poor protein-digestibility. When normal and high-protein digestibility mutant sorghum flours were cooked, predigested with protease, and analyzed for starch digestion rate, the high-digestibility lines showed substantially higher starch digestion than normal lines, comparable to those of corn and rice flour digestibility. In other work on slowly digesting/resistant starches, starch treatments were used that reduced digestibility by 30-35%. In a study on variability of rice functional properties due to growing location (Project 30), it was found that amylose content was significantly higher in rice grown in Missouri compared to Arkansas or Texas, and this corresponded to differences in starch pasting and whole cooked rice properties. Additionally, amylopectin fine structure and average molecular weight showed some differences due to growing location. Studies were completed on localization and influence of granule-associated proteins on starch behavior (Project 27; Papers B.22 and C.11). Using confocal laser scanning microscopy with the dye 3-(4-carboxybenzoyl)quinoline-2-carboxaldehyde, proteins in gelatinized ghost structures and in channels of native starch granules were visualized. Gelatinized ghosts were found to be enriched with protein leading to the speculation that proteins may help maintain ghost structure. Proteins were also found to line the channels of native isolated corn starch, as well as being present in the starch matrix in cross-sections of developing corn endosperm.

Three important advances came from Dr. BeMiller's laboratory: (1) development of a simpler more rapid method to locate sites of reaction within granules, (2) development of a method to determine the degree of granule channelization (susceptibility to digestion), (3) further understandings of starch-food gum (hydrocolloid) interactions. (1) It was hypothesized and proven that anionic substituent groups can be converted into silver salts that withstand washing, the silver ions can be easily reduced to silver atoms, and the silver atoms can be located by

reflectance confocal laser scanning microscopy (Project 2). (2) It was determined that the degree of channelization observed microscopically is correlated with the rate of raw granule digestion with glucoamylase, and a standardized method to measure this rate was developed (Project 1). (3) It was found that the effects of a gum on starch pasting curves was specific for a specific starch and a specific gum and that the one generalization that can be formulated at this time is that anionic gums significantly decrease the peak viscosity of potato starch (Project 8; Paper B.1). In a related project, it was found that dry heating of starches impregnated with anionic gums gave them characteristic similar to those of lightly crosslinked starches, with perhaps potato starch again being an exception (Project 33; Paper C.1). With regards to oxidation of starch in the presence of protein, it was found that tapioca starch behaved very differently from other starches (Project 3).

### **Molecular Structures and Properties of Hydrocolloids:**

Dr. Chandrasekaran's group has uncovered the structural details of the junction zone in alginate gels (Paper A.12) and  $\kappa$ -carrageenan gels (Project 19; Papers A.14 and B.14) and the structure-function relationships in RMDP17 belonging to the gellan family (Project 18; Paper B.12) and in bejieran (Project 20; Paper B.13)

### **Rheology:**

Dr. Campanella's group has worked on the modeling of a dough divider. A fluid mechanics model allowed them to optimize the design of the die to handle a range of doughs with different rheology. The optimized design can produce dough pieces with uniform weight for a range of dough formulations (Project 11, Paper B.9). A fluid mechanics model was utilized to describe the sheeting of narrow sheets. This model is setting the basis for the analysis of cereal flaking (Project 17, Papers A.8, B.6, B.7). The effect of milling conditions on the rheology and stickiness of wheat dough was also investigated by Dr. Campanella's group (Project 13, Paper D.24). And they are investigating the phenomenon of puffing and the physical chemical characterization of porous materials (Project 12, Papers B.8, B.11, D.12, D.36). Rheological properties of liquids are being determined using acoustic methods. By changing the frequency the method can be used to determine shear viscosity of the liquid at low frequency whereas the extensional viscosity of the liquid can be measured at an ultrasonic frequency (Project 14, Paper D.37).

### **Interfacial Phenomena:**

Dr. Narsimhan and his students have quantified the effect of protein-surfactant interactions on emulsion and foam stability (Project 38). Span 80, an oil-soluble surfactant, was found to displace  $\beta$ -lactoglobulin from the oil-water interface at sufficiently high concentrations as indicated by interfacial tension values and a reduction in interfacial rheological properties. This reduction in interfacial rheology at high Span 80 concentrations resulted in poor emulsion stability and a reduction in coalescence time of a single oil droplet at the oil-water interface. Similar behavior was observed for the water-soluble surfactant Tween 20, i.e. Tween 20

displaced  $\beta$ -lactoglobulin from the air-water interface at sufficiently high surfactant concentration, leading to poor foam stability. Dr. Narsimhan and his students have also initiated experiments to investigate the effect of conformation of proteins on their ability to stabilize foams (Project 39). Magnetic Resonance Imaging has been employed to obtain the evolution of the moisture profile during draining in protein-stabilized foams. A mathematical model has been developed to describe drainage and collapse of protein-stabilized foams in terms of colloidal interaction forces.

### **Water Relationships and Thermal Events:**

Dr. Cornillon's group developed an ultrasound sensor to evaluate the effects of freezing conditions on physical property changes of foods (Project 22). Complex mathematical algorithms like wavelet analysis were implemented to obtain insight on how the internal physical structure of a frozen product could affect the propagation of waves. In addition, ice and unfrozen water contents were spatially monitored in the product over a broad range of temperature using SPRITE MRI. Combining both techniques could be very valuable for the understanding of the effects of storage and temperature fluctuations in the overall quality of frozen foods.

NMR was also successfully used to characterize the rehydration of powders, namely caseinates, sugars, gums, and starches, in aqueous systems. Measuring the relaxation times provided a tool to monitor dispersion and hydration kinetics of these powders.

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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
- Mono- and oligosaccharide chemistry
- Uses of carbohydrates in food and other commercial applications

### **Osvaldo H. Campanella**

#### *GENERAL RESEARCH AREAS*

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

#### *SPECIFIC RESEARCH AREAS*

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

## **R. Chandrasekaran**

### *GENERAL RESEARCH AREAS*

- X-ray diffraction
- Molecular modeling

### *SPECIFIC RESEARCH AREAS*

- Conformations of biopolymers
- Structure-function relationships and molecular structures of polysaccharides, nucleic acids, and polypeptides
- Computer modeling of polysaccharide-polysaccharide, protein-polysaccharide, protein-nucleic acid, and nucleic acid-drug complexes

## **Paul Cornillon**

### *GENERAL RESEARCH AREAS*

- NMR spectroscopy
- MRI
- Freezing phenomena

### *SPECIFIC RESEARCH AREAS*

- NMR/MRI applications to food science and food engineering; development of in-line, on-line, and off-line techniques
- Determination of water distribution and interactions
- Characterization of structure and texture, including the influence on them of composition, constituents, and experimental conditions
- Freezing of foods (formation of ice crystals, stability of frozen foods, quality changes, freezing damage)
- Glass transition and mobility
- DSC, DETA

## **Bruce R. Hamaker**

### *GENERAL RESEARCH AREAS*

- Cereal chemistry
- Cereal component functionality and digestibility

### *SPECIFIC RESEARCH AREAS*

- Cereal chemistry and technology
- Cereal starch and protein functionality and digestibility
- Textural properties influenced by starch fine structure
- Interactions between starch and other food components
- Use of immunological techniques in quantification and localization of specific cereal proteins in normal and mutant cereal genotypes
- Appropriate methods of improving cereal utilization in developing countries
- Cereal endosperm texture
- Electron and confocal microscopy of cereal components

## **Rick P. Millane**

### *GENERAL RESEARCH AREAS*

- Mathematical and computational modeling
- X-ray diffraction

### *SPECIFIC RESEARCH AREAS*

- Molecular structures, interactions, and dynamics of polysaccharides
- X-ray fiber diffraction analysis
- Theoretical and computational crystallography
- Diffraction by disordered polymer systems
- Statistical mechanical modeling of polymers and gel systems
- Mathematical and computational modeling

# **Ganesan Narsimhan**

## *GENERAL RESEARCH AREAS*

- Emulsions and foams
- Biopolymer interactions

## *SPECIFIC RESEARCH AREAS*

- Stability and texture of food emulsions and foams
- Adsorption of proteins and protein-polysaccharide complexes at interfaces
- Functional properties of proteins and protein-polysaccharide complexes
- Physical and chemical modification of proteins for use as food stabilizers
- Rheology of polysaccharide solutions and gels

# **Bradley L. Reuhs**

## *GENERAL RESEARCH AREAS*

- Polysaccharide analysis
- Plant cell wall compositions, structures, and functions
- Bacterial cell wall compositions, structures, and functions

## *SPECIFIC RESEARCH AREAS*

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

## **Roy L. Whistler**

### *GENERAL RESEARCH AREAS*

- Starch chemistry
- Industrial gums

### *SPECIFIC RESEARCH AREAS*

- Chemistry, structure, design, and use of carbohydrates in medicine, foods, and nonfoods
- Basic science and applications of carbohydrates
- Starch
- Reactions of carbohydrates
- Systems for microtransport of drugs, flavors, insecticides, etc.

## **ADJUNCT FACULTY**

**Struther Arnott**, Institute of Cancer Research, London, is a collaborator in x-ray diffraction analysis.

**Yonas Gizaw**, a Senior Research Scientist, Food and Beverage Technology Division, The Procter & Gamble Co., was awarded the Ph.D. degree by Purdue University (J.N. BeMiller, advisor) in August 1996 and has been with Procter & Gamble since then.

### *RESEARCH INTERESTS*

- Behaviors of starches and polysaccharides in the presence of other food ingredients
- Molecular basis of functionalities
- Synthesis of biologically active monosaccharide derivatives (collaboration with Drs. BeMiller and Duy-Phong). (Project 4)

## GRADUATE STUDENTS

**Shyamsunder Baskaran** earned a B.S. degree in metallurgical engineering from Indian Institute of Technology, Madras. He joined Dr. Millane's research group in October 1994 and is now in the Ph.D. program. His research project involves new computational methods for locating guest molecules (e.g. counter ions and solvent molecules) in polysaccharide crystal systems (Project 36). Shyam completed an M.S. degree July 2001.

**Wen Bian** earned B.E. and M.S. degrees in food science and engineering from Ocean University of Qingdao, China. He joined Dr. Chandrasekaran's group in the Fall of 1997 as a Ph.D. student. His research topic was on the structure-function correlations of four industrially important polysaccharides (Projects 18 and 20). He graduated in December 2001 (Thesis E.1) and enrolled as a graduate student in the Computer Science Department at Purdue.

**Betty Bugusu** joined Dr. Hamaker's group in January 1998 to pursue her graduate degrees. Betty comes from the Kenyan Agricultural Research Institute and received her B.S. degree from Egerton University in Kenya in 1991. Betty works on the USAID-funded INTSORMIL project. Her M.S. research focused on improving the functionality of non-wheat proteins in breadmaking systems. She received her degree in May 2000 and is continuing her doctoral work studying slowly digesting starches (Project 26).

**Stephen Christanto** obtained two B.S. degrees from Purdue University: Chemical Engineering (May 1998) and Food Process Engineering (May 1999). Stephen, originally from Indonesia, came to the U.S. in 1992 to finish high school and to Purdue in 1994. As an undergraduate, Stephen did bioseparation research in the Chemical Engineering Department under the guidance of Dr. Linda Wang. He joined Dr. Campanella's group for the M.S. program in Food Process Engineering in May 1999. Stephen also took a 6-month internship in Production Technology at Kellogg Company in the Spring of 2001. Stephen's research deals with dough rheology and investigating the effect of processing on the stickiness and rheological properties of wheat dough (Project 13).

**Anna Marie Duldulao** graduated with a B.S. degree in Agricultural Chemistry from the University of The Philippines at Los Banos in 1994. After graduation, she worked as an analytical chemist, first for the university and then for two private sector companies. Anna Marie entered the graduate program in food science as an M.S. student of Dr. BeMiller in June 1999. Anna Marie completed degree requirements in May (Thesis E.2). Her thesis project was a study of the pattern of acid-catalyzed hydrolysis of hydroxypropylated starch granules (Projects 6 and 9).

**Jonathan L. Eads** earned a B.A. degree, Cum Laude, in Physics from Central College, in Iowa. He was awarded a USDA National Needs Fellowship in 1995 and began study towards the Ph.D. degree in Dr. Millane's laboratory. His research project was concerned with modeling of, and diffraction by, disordered polymer systems. He completed degree requirements in May (Thesis E.3, Project 35).

**Abhishek Goyal** earned an M.S. degree in biotechnology from Indian Institute of Technology, Delhi. He joined Dr. Millane's laboratory in August 1998 to pursue a Ph.D. degree. His research project is concerned with modeling and analysis of the myosin lattice in muscle, and simulation of polymer chain configurations in solution (Projects 35 and 37). Dr. Narsimhan is now his advisor.

**Ninik Gunawan**, from Indonesia, graduated from Purdue (B.S. in Food Science) in May 1999 and entered the graduate program in Food Science in August 1999. Her M.S. research project involves determination of the influence of genetics on channelization of starch granules (Project 1). Her advisor is Dr. BeMiller.

**Jonathan Gray** earned a B.S. degree in Food Science with honors from the University of Arkansas at Fayetteville in May 1998 and began as a Masters' degree student of Dr. BeMiller in August 1998. In December 1999, it was judged that Jonathan had earned the right to bypass the M.S. degree and enter the Ph.D. program. Also in 1999, Jonathan was a member of the national-award-winning IFT Product Development Team. He spent an internship semester at the Miami Valley Laboratory of the Procter & Gamble Co. during the Fall of 2000. Jonathan is the President of IFTSA. His Ph.D. research is a study of the effects of reaction conditions on derivatization of starch granules (Project 2).

**Dennis Kim** graduated in May 1998 from Purdue University with B.S. degrees in Biochemistry and Food Process Engineering. As an undergraduate, he was engaged in a Co-Op program with the USDA in their Fermentation Biochemistry Research Unit. Dennis joined Dr. Narsimhan's group in 1997. His Masters' degree research in Food and Bioprocess Engineering involved changes in interfacial and physicochemical properties of model food proteins as a function of their modification. In August 2000, Dennis completed M.S. studies and joined Kraft Foods, where he previously had done a summer internship.

**Yong-Ro Kim**, who joined Dr. Cornillon's group in January 1998, earned a B.S. degree in Food Science & Technology from Seoul National University, Korea, then worked at Korea Institute of Science and Technology for a year before entering graduate school. He completed his M.S. degree in the Fall of 1997 under the supervision of Drs. Morgan and Okos. His thesis research topic was dielectric properties of baked biscuit dough. He completed the Ph.D. requirement in Spring of 2001 (Thesis E.5). His Ph.D. project was characterization of physicochemical changes in hard wheat flour dough during processing (Project 24). Yong-Ro is now working with Dr. Tim Haley in the Purdue Food Science Department on NMR and Raman spectroscopy applications to foods.

**Sung Ho Lee** earned his B.S. degree in Food Science and Technology and M.S. degree in Agricultural Biotechnology from Seoul National University, Korea. His M.S. research involved modulation of cyclizing and hydrolyzing activity of thermostable cyclodextrin glucoamylase and its application as antistaling enzyme. He joined Dr. Hamaker's group in January 2001 to pursue a Ph.D. degree. His research project is on structural properties of hard-to-digest proteins and its relationship to potential allergenicity.

**Suyong Lee** earned B.S. and M.S. degrees in Food Science and Technology from Seoul National University, Korea. His M.S. research involved studying the effect of amylases on the retrogradation and flavor of bread. He joined Dr. Cornillon's group in January 2000 and worked on application of NMR and ultrasonic techniques to frozen foods (Project 22). Dr. Campanella is now his Advisor (Project 16).

**Leon Levine** is presently president of Leon Levine and Associates, a consulting firm. He holds B.S. and M.S. degrees in chemical engineering from The City College of New York and is currently engaged in Ph.D. studies at Purdue (Project 17). He has more than 30 years of food process and product development and engineering experience, including employment with Pillsbury and Procter and Gamble. In addition to his industrial experience, he has lectured on food processing at the University of Minnesota and regularly teaches continuing education courses about food process scale-up, extrusion, and food engineering for the American Association of Cereal Chemists, Rutgers University, and private clients. He has published approximately twenty papers and a number of book chapters on food processing and scale-up. He has coauthored a textbook, Food Processing Operations and Scaleup, and holds a number patents related to food processes and products. In addition to being a regular columnist on food engineering in Cereal Foods World, he is on the editorial boards of the Journal of Food Engineering and the Journal of Food Process Engineering.

**Michele Maladen** comes from New Delhi, India and holds a B.S. degree in Chemistry from St. Stephen's College, Delhi University. She joined Dr. Hamaker's group in June 2000 to pursue a M.S. degree. Michele's research focuses on better understanding and potential application of a previously identified three-component (starch-protein-fatty acid) complex (Project 25).

**Bridget Ryan Manis** graduated with a B.S. degree in Food Science from the University of Missouri and began as a Master's degree student in Dr. Chandrasekaran's laboratory in January 1996. Her M.S. thesis described molecular-level details of the "egg-box" model of alginate and pectate gels. Bridget completed requirements for her M.S. degree in 1997, and then became a Ph.D. student of Dr. BeMiller. She completed degree requirements in November (Thesis E.6). Her Ph.D. thesis topic involved finding new, more natural ways to modify starch behaviors (Project 3). Bridget is now employed at Frito-Lay.

**Behic Mert** earned a B.S. degree in Food Engineering from Middle East Technical University, Turkey. After working in the bakery industry for two years as food engineer, he began as a Master's degree student at Michigan State University in 1998. His M.S. research involved improving mechanical and barrier properties of whey protein isolate films as a packaging material. He came to Purdue in January 2000 and is now a Ph.D. student of Dr. Campanella. His Ph.D. thesis research involves rheological characterization of materials with acoustical methods (Project 14).

**Belén Prado**, from Honduras, began pursuit of an M.S. degree following an internship in Purdue's Food Science Department and graduation from Zamaron Pan American School of Agriculture in Honduras. Her research concentrates on the role of soluble branched and linear glucans of differing molecular weights on the textural properties of adhesiveness and cohesiveness (Project 31). She works under the advisement of Dr. Hamaker.

**Allison E. Ray** earned a B.S. degree in Agricultural and Biological Engineering, with a specialization in Food Engineering, from Purdue. She joined Dr. Narsimhan's group in August 1999 and is working toward an M.S. degree. Her research project involves protein and surfactant interactions and how these interactions work to stabilize emulsions (Project 38).

**Joshua D. Reid** joined Dr. Campanella's research group in January 2000. He received a B.S. degree from Purdue University's School of Chemical Engineering in 1995. Subsequently, he entered food research as an M.S. student at the University of Arkansas, where his thesis research involved studying the effects of drying conditions on rice quality. Having completed his M.S. degree in 1998, he interned for a year at Kellogg Company before matriculating in our Ph.D. program. Joshua's research is focused on developing design methods for dough processing that incorporate the complex rheology of the system (Project 11). Joshua has accepted a position with General Mills.

**Kelly Anne Ross** joined Dr. Campanella's research group in August of 1999. She earned a B.S. degree with distinction in Food Science in 1996 from the University of Manitoba, and obtained an M.S. degree in Food Science from the same university in 1999. Her Master's thesis research involved studying the texture of french fries from a fundamental mechanics approach. Prior to officially graduating and starting her studies at Purdue, Kelly interned at the Procter & Gamble Company. Kelly's Ph.D. program involves completing courses required to become an ABET accredited engineer while performing research directed towards characterizing the phenomenon of extrudate expansion and the mechanical properties of extrudates (Project 12).

**Michelle Rzonca** earned a B.S. degree in Food Science from Purdue University in May 1999. She joined Dr. Cornillon's group in August 1999 to earn an M.S. degree. Her research project involved texture determination during fermentation of yogurt made with varying yogurt strains (Project 21). Michelle graduated in August (Thesis E.7) and now works at Hormel in Minnesota.

**Budhi Suhendra** worked for much of his undergraduate student years in Dr. Hamaker's lab, and following the completion of his B.S. degree in Food Science from Purdue in May 2000, he entered the M.S. program. Budhi is from Indonesia. His research project is designed to identify ways to achieve high starch digestibility in sorghum grain for animal feed purposes (Project 29). Dr. Hamaker is his Major Professor.

**Jonathan A. Stapley** entered our graduate program in August 2000, having been awarded one of Purdue's prestigious Frederick N. Andrews Doctoral Fellowships. Jonathan graduated with a B.S. degree from the Department of Food Science, Brigham Young University. While an undergraduate student, he was employed as summer interns at West Agro (Kansas City) (twice) and at Nestle SA (Amiens, France). He also did an 8-month internship at W.K. Kellogg Institute of Food and Nutrition. Jonathan's major advisor is Dr. BeMiller. The goal of his thesis project is to determine if there are subpopulations of starch granules that react differently from other populations (Project 5).

**Agung Tandjung** graduated with a B.S. degree in Food Science from Purdue and joined Dr. Hamaker's group in August 1998 in the M.S. degree program. Originally from Indonesia, Agung came to the U.S. in 1995 following a year-and-a-half of study in British Columbia. He obtained his M.S. degree in August 2000 on work on the role of corn zein protein in the functionality of breakfast cereal products. His Ph.D. research is focused on popcorn quality (Project 32).

**Zebin Wang** earned a B.S. degree in Chemical Engineering (July 1998) and a M.S. degree in Biochemistry (June 2001) from Tsinghua University, P.R. China. His M.S. research focused on "Activities and Physico-chemical Properties of Rice PHGPx". He came to Purdue as a Ph.D. student in Dr. Narsimhan's group in August 2001. His research project involves protein-stabilized thin films (Project 39).

**Kevin Wright** graduated with his B.S. and M.S. degrees in Food Science from Brigham Young University. His Master's thesis research involved the compositional comparison and characterization of starch from *Atriplex hortensis* and *Chenopodium quinoa* seeds. Kevin interned with the Kellogg Company for 8-months in 1998 and was a student intern in Bolivia for the Ezra T. Benson Agriculture and Food Institute. He joined Dr. Hamaker's group in August of 2001 to pursue a Ph.D. degree.

## RESEARCH SCIENTISTS AND ASSOCIATES

**Dr. Adam Aboubacar** earned a B.S. degree at Kansas State University, then an M.S. degree (1991) at Purdue under the direction of Dr. Allen Kirleis. He joined Dr. Hamaker's research group in 1993 after a return to his home country, Niger. His Ph.D. research project involved determination of starch and grain properties that affect the quality of sorghum-based couscous. He was also involved with setting up an entrepreneurial-scale, couscous processing unit in Niger. Adam was awarded his Ph.D. degree in December 1997, has worked as a post-doctoral Research Associate in Dr. Hamaker's lab, on 2 projects – development of a high throughput screening assay for a high protein-digestibility sorghum mutant and investigation into variability in rice functionality, and is seeking employment (Project 26 and 30).

**Dr. Xianzhong Han** obtained B.S. and M.S. degrees in biology from Hangzhou University in the P.R.C. in 1982 and 1987, and received a second M.S. degree in cereal chemistry from Montana State University in 1996. He joined Dr. Hamaker's lab in January 1998 and received his Ph.D. degree in the Spring of 2001 (Thesis E.4). His doctoral thesis research was principally on starch granule-associated proteins -- their affect on starch gelatinization behavior and location with the starch granule structure. Han has continued with Dr. Hamaker as a post-doctoral research associate. His current work is on new approaches for developing slowly digesting or resistant starches with adequate functional properties (Projects 27 and 28).

**Dr. Srinivas Janaswamy** earned a Ph.D. degree in 1997 from the Department of Physics, Indian Institute of Technology, Madras. His doctoral dissertation was on the x-ray structural analysis of inorganic compounds in both single crystals and polycrystalline specimens. He joined Dr. Chandrasekaran's group in July 1999 and is conducting x-ray fiber diffraction and molecular modeling studies on industrially useful polysaccharides (Project 19).

**Dr. Hyesook Son Lim** earned a Ph.D. (1990) in the Department of Food Science at Kansas State University, followed by three years of post-doctoral studies in the Department of Food Science and Human Nutrition at Iowa State University, which in turn was followed by four years as a Research Associate in the Center for Advanced Food Science and Technology at Korea University. With Dr. BeMiller, she is developing a new method of sugar analysis (Project 10).

**Dr. Tuula Ojanen-Reuhs**, from Finland, received a Ph.D. degree in microbiology from University of Helsinki, Finland, in 2000. Her thesis research topic was cell-surface polysaccharides and proteins of *Xanthomonas campestris*. She did postdoctoral work at the Complex Carbohydrate Research Center of the University of Georgia, where she studied polysaccharide function in *Medicago truncatula*-*Sinorhizobium meliloti* symbiosis, *M. truncatula*, which is closely related to alfalfa, is being used as the model legume. In November 2001, she began post-doctoral work. Her research involves the analysis of complex polysaccharides from plants and bacteria (Projects 40, 41, and 42).

**Dr. Duy-Phong Pham-Huu** was born and raised in Viet Nam and received his higher education in Slovakia. He earned his Ph.D. from the Institute of Chemistry, Slovak Academy of Sciences in Bratislava, with a thesis on Synthesis of C-Glycosyl Analogues of Biologically Significant Glycosides. In May 1999, he began post-doctoral work with Dr. BeMiller, continuing the same line of investigation as part of an ongoing collaboration between the two institutes (Project 4).

**Dr. Xiaohong Shi**, a Research Scientists (Projects 6, 7, and 8), earned a B.S. degree in polymer physics from the Department of Applied Chemistry, University of Science and Technology of China, and an M.S. degree in the same field at Changchun Institute of Applied Chemistry, Academia Sinica. Nina, as she is known to us, completed Ph.D. requirements of our program under Dr. BeMiller's supervision in May 1998 and then was a post-doctoral Research Associate for three years before earning her current position.

**Dr. Jaeyong Shim** joined Purdue University in August 2000 as a postdoctoral Research Associate, after earning a Ph.D. degree from Cornell University. His research interests include rheology of cereals and gels. Dr. Shim is working in Dr. Campanella's laboratory on the rheological characterization of gels and how these properties are affected by processing (Project 13).

**Dr. Ratchapong (Lek) Wungtanagorn** earned a B.S. degree in Agriculture with first class honors and an M.S. degree in Food Science from Kasetsart University, Thailand. Lek worked as an assistant manager of the research and quality control department at United Food Public Co., Ltd., then became an instructor and researcher in the School of Biotechnology, Rangsit University, then entered the Ph.D. program in Agricultural Engineering with a specialization in Food and Bioprocess Engineering at University of Illinois at Urbana-Champaign. His Ph.D. research was a phenomenological study and mathematical modeling of enthalpy relaxation of sugars. Lek joined the Whistler Center as a postdoctoral Research Associate in May 2000. He is now employed by Mead Johnson & Co. in Thailand.

**Dr. Pingyi Zhang** joined Dr. Whistler's laboratory as a post-doctoral Research Associate in September 2000. Peter, as we know him, earned a B.S. degree in chemistry in 1995 from Wuhan University, China. He completed the Ph.D. program in polymer chemistry at the same university in June 2000. His research topic was chemical structure, solution properties, and anti-tumor activity of the polysaccharides from *Lentinus edodes*. Currently, he is working on the characterization of hemicelluloses and their uses in pharmaceuticals.

## VISITING STUDENTS, SCHOLARS, AND SCIENTISTS

**Professor Struther Arnott**, Institute of Cancer Research, London, England, and an Adjunct Professor in Purdue's Food Science Department, spent two weeks in Dr. Chandrasekaran's laboratory in June-July, participating in collaborative research on the x-ray structures of nucleic acids.

**Dr. Carlos M. Corvalan** was educated in Argentina, where he received a degree in Chemical Engineering from the University of Rosario and a Ph.D. in Computational Fluid Dynamics from the University of Litoral, Santa Fe in 1993. He then joined the faculty of the School of Bioengineering, University of Entre Rios, Argentina. In March 2000, he became a visiting scientist in Dr. Campanella's group. His research interests include modeling of food and biological processes in which interfacial forces play a preponderant role and in flows with free boundaries (Projects 11, 12, and 17).

**Jung-Ah Han** is a Ph.D. student in Dr. Lim's laboratory. Her research subject is characterizing chain profiles of amylopectins of various origins and their relation to rheological properties of pastes and gels. She is using a multi-angle laser light scattering detector and intermediate-pressure size-exclusion chromatography for chain structure analysis. Jung-Ah returned to Korea in January (Projects 33 and 34).

**Dr. Allan Hardacre** visited Purdue University for 1 month as part of a 7-week research Fellowship from Crop and Food Research in New Zealand. His recent research experience is in the fields of maize physiology. For the past 12 years, he has been responsible for the NZ corn breeding program. Part of this program has focused on the improvement of grain for the food industry, particularly for extrusion, flaking and other dry milling applications. While at Purdue, Dr. Hardacre worked with Dr Campanella's group, characterizing the rheological properties of roux formed from flours and starches derived from corn and wheat.

**Dr. Seung-Taik Lim**, a starch scientist and an Associate Professor in the Graduate School of Biotechnology, Korea University, spent about 8 months in the Whistler Center as a visiting scientist. Dr. Lim is a graduate of Korea University (B.S. and M.S. degrees) and received a Ph.D. degree from Kansas State University in 1990. After doing post-doctoral research at Iowa State University, he joined the faculty of Korea University. His research interests are structural analysis, modification, physical characterization, and utilization of starch polymers. His particular pursuit at the Whistler Center is heat treatments of starches with gums (Projects 33 and 34).

## **STAFF**

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# PROJECT SUMMARIES

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**1. Title: Channelization of Corn Starch Granules****P.I.** J.N. BeMiller**Researchers:** Ninik Gunawan, M.S. Student**Sponsor:** State of Indiana Value-Added Grant Program. Now available for sponsorship.**Objectives:** (1) Determination of the effect of genetic background, if any, on the extent of channelization in maize starch granules. (2) Determination of channel origin.

**Progress:** Objective 1: In 1992, we reported the presence of pores on the surface of corn starch granules and suggested that those pores might be openings to channels leading to the interior of granules. In 1993, we published preliminary evidence that there were indeed channels within corn starch granules. In 1997, we presented unequivocal evidence that channels connected the exterior surface of starch granules to the central cavity. In 2000, we presented evidence that the action of enzymes and penetration of reagents during modification of starch for food and industrial use is primarily from the center of corn starch granules outward. During this research, evidence was obtained that, with the starch of sorghum, a close relative of corn, the number of pores and channels per granule was a function of its genetic makeup. The question addressed by this research is whether the degree of channelization in corn starch granules can be changed by breeding.

It was hypothesized that the degree of channelization of corn starch granules could be altered by conventional breeding techniques. It also was hypothesized that a higher degree of channelization would make the corn and/or corn starch more valuable by providing more uniform access to modifying reagents and greater access to enzymes and, hence, greater digestibility of the starch and greater feed efficiency.

A method has been developed to quantitate the average number of channels per granule. The method involves digestibility with glucoamylase which is correlated with the general degree of channelization observed microscopically.

14 Endosperm mutants from two maize backgrounds (B73 and Oh43) were examined. In all but two cases (su2 and ae), the degree of channelization in those with a Oh43 background was significantly greater than those with a B73 background. 16 Selfed, 2<sup>nd</sup> generation crosses of these endosperm mutants were also examined. Results confirm that there is, and can be, differences in the average degree of channelization of corn starch.

Objective 2: Using different techniques, it has been discovered that channels are lined with substances containing free primary amino groups (protein molecules) (Paper B.22) and with anionic substances (protein molecules) (Paper D.23). From this information, we hypothesize that maize and sorghum amyloplasts contain microtubules arranged like the spokes of a wheel and that granules form around them so that the embedded tubules form the observed channels.

**Status:** Active.

**2. Title: Reaction Sites of Corn Starch Granules**

**P.I.** J.N. BeMiller

**Researcher:** J. Gray, Ph.D. Student

**Sponsor:** USDA. Now available for sponsorship.

**Objectives:** (1) Location of the sites of reaction in derivatized corn starch granules. (2) Determination of effects of pH, temperature, kind of salt, and salt concentration on patterns of derivatization.

**Progress:** A possibility of making higher value starch products using available commercial starches and allowable reagents and levels of addition is control of where the low level of modification takes place within or on granules. The results should expand our understanding of the natures of starch granules and have the potential of providing information that could be used to develop new, commercial, value-added starches through process control. However, any new products of starch derivatization for food use, with new properties and which impart improved functionalities, must be made using existing approved reagents within existing limits of reagent use and/or add on. The basis for this project is that this is potentially possible. The hypothesis is that granule architecture influences patterns of reaction during chemical modification. Knowledge of granule microstructure provided so far in this study has advanced understanding of starch granule reactivity.

Before undertaking a determination of any effects of pH, temperature, kind of salt, or concentration of salt on the homogeneity/heterogeneity of granule derivatization, a method was sought that was simpler and faster than the method developed earlier (by us) (back-scattered electron imaging) i.e., one which avoids the lengthy sample preparation required for electron microscopy.

It appears that a much more convenient method has been developed. However, not all controls to make certain that what is being observed is not artifactual, have been completed. The method involves reacting starch with reagents that introduce anionic substituents (phosphate ester groups and a sulfonate analog of hydroxypropyl ether groups). Then, the anionic substituent groups are converted into silver salts and excess silver ions are removed by washing. Following reduction of the silver ions to silver atoms with ascorbic acid, the granules are examined with a confocal scanning laser microscope in the reflectance mode. Reflection of the laser beam from the silver atoms can be detected (Paper D.23). Much work has been done to convince ourselves and others that the silver atoms are at the sites of anionic groups and only at the sites of these groups. This phase has been completed. An advantage of reflectance CLSM over fluorescence CLSM is that photobleaching of sample is not a concern. To eliminate inherent reflectance of laser off granular edges or surfaces, granules were viewed in 20% sucrose solution. This method is being applied to study the effects of modification reactions conditions on the location of reaction sites within starch granules.

**Status:** Active.

**3. Title: Starch Modification with Proteins**

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

**Researcher:** B. Ryan Manis, Ph.D. Student

**Objective:** Modification of starch cooking and paste behavior using natural products.

**Progress:** This research was undertaken to modify starch with natural products, namely proteins. Motivation for this project was a 1943 patent by A. D. Fuller which described a modified starch product made with various substances in the presence of small amounts of hypochlorite (NaClO) that behaved like a crosslinked starch (characterized by an increase in peak viscosity and a decrease in breakdown). The specific objectives of this research were to: 1) reproduce the reported preparation of crosslinked starches via oxidation in the presence of proteins, 2) optimize the reaction, and 3) determine the nature of the chemical crosslinks.

Starch was modified by oxidation with NaClO in the presence of various proteins. After modification, excess protein was washed from the granules with water. The reported preparation of crosslinked starches via oxidation in the presence of proteins could be reproduced with (in the only patent) tapioca starch. With common corn, waxy corn and potato starch, oxidation alone was enough to increase peak viscosity and decrease breakdown as determined by rapid viscoanalysis; little difference was obtained with added protein. Oxidation of tapioca starch in the presence of soy isolate protein was optimized using statistical response surface methodology. Determination of the nature of the crosslinks was attempted by determining the amount of protein remaining in tapioca starch granules oxidized in the presence of protein and comparing the value to the value for control starches. The results were not conclusive, as oxidation of protein decreased the amount of measurable protein. The conclusions were that the reaction of Fuller works somewhat with tapioca starch, but not with any other starch tested, and that the oxidation of starch in the presence of protein is not an effective method of crosslinking.

**Status:** Completed. Thesis E.6

**4. Title: C-Glycosyl Compounds**

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

**Researcher:** D.-P. Pham-Huu, Ph.D. Research Associate

**Collaborators:** L. Petruš, Slovak Academy of Sciences

Y. Gizaw, The Procter & Gamble Co.

**Objective:** Development of general methods for synthesis of C-glycosyl compounds, especially compounds with useful biological activity.

**Progress:** Syntheses of sugar analogs in which the ring oxygen atom has been replaced by an NR group (azasugars) or the anomeric hydroxyl group has been replaced by a carbon atom (C-glycosides) have been subjects of intensive research interest in recent years. Many members of both classes of compounds are specific inhibitors of glycosidases, including enzymes involved in glycoprotein processing, glycogenolysis, and oligo- and disaccharide hydrolysis, and as such can have important biological activities with potential therapeutic applications. In spite of recent developments in the synthesis of C-glycosides and azasugars, stereospecific formation C-glycosides and aza-C-glycosides remains a challenge. New ways to prepare C-glycosides and aza-C-glycosides have been developed in our laboratory. Most recently, we have developed a simple stereospecific approach to both C- $\alpha$ - and  $\beta$ -D-arabinofuranosylformaldehyde dithioacetals from hexoses (Paper D.16). Since arabinofuranosyl units are important constituents of glycoconjugates from many lower organisms, including bacteria, parasites and fungi, and C-glycosylformaldehyde dithioacetals are convenient synthons for a number of subsequent reactions, their easy availability offers interesting prospects for synthesis of pharmacologically-active carbohydrate mimics.

We have also found that treatment of 4-azido-4-deoxy-2,3:5,6-di-O-isopropylidene-D-galactose propane-1,3-diyl dithioacetal (derived from D-glucose) with mercuric chloride and mercuric oxide in methanol affords the corresponding dimethylacetal. Reductive amination and acid-catalyzed deprotection of the azido dimethylacetal, followed by catalytic hydrogenation, gives 1,4-dideoxy-1,4-imino-D-galactitol in good yield (Paper B.2), an azasugar. The importance of this work is that both natural and unnatural polyhydroxylated pyrrolidines and piperidines (azasugars) are glycosidase and glycosyltransferase inhibitors and that many azasugars that inhibit glycosidases or glycotransferases have been found to be potential chemotherapeutic agents for treatment of diseases such as diabetes and cancer, inflammation, and viral infections, including HIV.

**Status:** Active.

**5. Title: Relationship of Starch Granule Subpopulations to Reactivity**

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

**Researcher:** Jonathan A. Stapley, M.S. Student

**Sponsor:** Available for sponsorship

**Objective:** Determination of starch granule reactivity as a function of granule subpopulation type.

**Progress:** It is well established that (1) starches from different botanical sources differ in appearance and chemical and physical properties and (2) the population of granules in a given starch preparation is heterogeneous, from some sources more so than others. From this information, it can be hypothesized that there are various subpopulations of granules within a preparation from a single botanical source that differ in some way.

Normal corn, potato, and wheat starches have been hydroxypropylated, then separated into two size fractions by sedimentation. Using image analysis, histograms of the fractions have been obtained. Future work will include determination of MS values for the whole starch and the subpopulations, determination of the thermal properties of the subpopulations, determination of the MS values of the amylose and amylopectin fractions of the subpopulations, and determination of the degrees of channelization of the subpopulations (unmodified) of corn and wheat starches.

**Status:** Active.

**6. Title: Openness of Derivatized Starch Granules**

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

**Researchers:** A.M. Duldulao, M.S. Student  
X. Shi, Ph.D. Research Scientist

**Objective:** Determination of how derivatization changes accessibility of granules to water and aqueous solutions.

**Progress:** The effects of acid on native and low-substituted (molar substitution *ca.* 0.1) hydroxypropylated common corn, waxy maize, potato, and tapioca starches under mild conditions was examined. Susceptibility to acid-catalyzed hydrolysis of these starches derivatized in the presence of sodium sulfate and sodium citrate (as swelling and gelatinization inhibitors during the modification process) was also compared. Definite differences were observed in the rates of hydrolysis of the native and etherified starches. Differences were also observed between starches from different botanical sources.

Results suggest that hydroxypropylation, even at a low degree of substitution, markedly increases accessibility of the starch granules to aqueous acid. Depolymerization of the four modified starches was 2-4 times more rapid than hydrolysis of their native forms. Also, for all modified starches examined, the molar substitution (MS) of the fragments solubilized during initial stages of hydrolysis was greater (about double) than the MS of the overall starch prior to acid treatment. This suggests that either more open areas within the granules or a subpopulation of more highly substituted granules was preferentially attacked by acid. Whether sodium sulfate or sodium citrate (which is more effective in inhibiting swelling) was used during derivatization did not appear to affect the rate of hydrolysis. Hydrolysis under similar conditions of corresponding amylose fractions from hydroxypropylated common corn starch samples with overall granule MS values of 0.02 – 0.13 showed a slight decrease in hydrolysis rate as the MS increased, suggesting that, at the molecular level, an increase in the number of hydroxypropyl substituents may increase the energy barrier that must be overcome to change conformation and effect hydrolysis of the glucosidic linkages. Thus, the

predominant effect of derivatization in making starch granules more susceptible to acid-catalyzed hydrolysis is on the granule structure.

**Status:** Completed.

7. **Title: Effect of Hydroxypropylation on Starch Polymer Leaching**

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

**Researcher:** X. Shi, Ph.D. Research Scientist

**Objective:** Determination of how derivatization alters leaching of amylose molecules from common corn starch granules.

**Progress:** Aqueous leaching of hydroxypropylated common corn starches at different times and temperatures was conducted. Results indicated that the greater the modification the easier it was for amylose molecules to leach out and that the preference for leaching of derivatized amylose decreased as the MS of the whole starch increased. (Paper B.3)

**Status:** Completed. Thesis E.2.

8. **Title: Effect of Gums on Starch Pasting and Paste Characteristics**

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

**Researcher:** X. Shi, Ph.D. Research Scientist

**Sponsor:** Available for sponsorship

**Collaborator:** J. Shim, Ph.D. Research Associate

**Objective:** Examination of the effect of various gums in solution on gelatinization and pasting of common corn, waxy maize, and potato starches and the paste viscosity.

**Progress:** There are literature reports of studies of the effects of gums on starch pasting and paste viscosities. These studies were done with either a Brabender ViscoAmylograph or an RVA, both instruments which are insensitive to low viscosities. To examine what happens during the early stages of cooking, a Brookfield viscometer was used for viscosity measurement while employing a Brabender ViscoAmylograph and its programs for heating.

Pasting curves of starches in gum (hydrocolloid) solutions at low concentrations (starch 3.6%, gum 0.4%) were produced with a Brookfield viscometer. Gums produced a variety of effects on viscosities of starches during starch pasting (increase or decrease greatly or slightly or no effect). A viscosity increase before the normal starch pasting temperature was detected for normal maize starch in the presence of CMC, gellan, xanthan, guar gum, and sodium alginate. Waxy maize, waxy rice, tapioca, regular rice, potato, and wheat starches gave mixed responses. It appeared that interactions between certain leached molecules, primarily amyloses, and certain gums were responsible for the viscosity increase occurring before starch pasting.

The pasting peak viscosity of potato starch was greatly decreased by negatively charged gums (CMC, carrageenans, alginate, xanthan). The repelling forces between the phosphate groups on potato starch and the negative charges on molecules of these gums

were hypothesized to be the cause. This hypothesis was supported by results from similar systems (potato starch plus salt solution and phosphorylated normal maize starch plus anionic gums), both of which systems also produced lower peak viscosities. It was found, by microscopic examination of potato starch heated to 95°C in solutions of ionic gums without shear, that anionic gums altered the potato starch granule pasting process. (Paper B.1)

**Status:** Active.

**9. Title: Determination of the Degree of Phosphate Crosslinking in Starch Granules**

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

**Researcher:** A.M. Duldulao, M.S. Student

**Objective:** Development of a simple accurate method for determining the amount of phosphate crosslinking in starch granules.

**Progress:** The only reported method for determination of the degree of phosphate crosslinking in starch granules is a <sup>31</sup>P-nmr method. The objective of this project was to develop a more accessible method. The principle being followed was the following. Crosslinked starch (phosphorylated) can be converted into a suitable salt which then can be analyzed for phosphorus and cation content. Monostarch phosphate would have a metal ion:phosphorus ratio of 2:1 while the distarch ester (crosslinking groups) would have a ratio of 1:1. So all ratios should fall within those limits and a simple calculation would give relative amounts of each. Using this figure and the total amount of phosphorus incorporated, the actual amounts of crosslinking and non-crosslinking phosphate ester groups could be calculated.

We found that silver salts work best because of the low-degree of dissociation during the washing step. However, it was ultimately determined that, although the method works, it does not have the required sensitivity for starches crosslinked by reaction with phosphoryl chloride.

**Status:** Terminated.

**10. Title: Constituent Analysis of Polysaccharides and Food Products**

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

**Researcher:** H. Lim, Ph.D., Research Associate

**Sponsor:** Available for sponsorship

**Objective:** Develop a faster, easier, more quantitative method of determining the monosaccharide constituent ratio of a polysaccharides.

**Progress:** A new method of non-destructive solvolysis and conversion of each constituent sugar into an aromatic derivative has been established. Efforts are now underway to separate these compounds by hplc.

**Status:** Active.

**11. Title: Computer-aided Design of Cereal Processes**

**P.I.** O.H. Campanella

**Researchers:** Joshua Reid, Ph.D. Student  
Carlos Corvalan, Visiting Scientist

**Sponsor:** MAFMA and Cummins Eagle

**Objective:** The main objectives of the research work are (1) to characterize the geometry of major equipment involved in the main operations of dough processing. That includes auger, dough developer, metering pumps, manifold and forming die. (2) to use commercial CFD packages that incorporate rheological models and complex geometries (e.g 3D geometries) to describe the behavior of dough on dough processing equipment. (3) to determine strain and stress profiles and optimize dough processing equipment.

**Progress:** Dough processing is moving to a new era of automation and dough properties need to be maintained within narrow ranges for a proper control. Dough processing involves operations under which the material is subjected to stresses and deformations of different types and magnitudes. These operations apply energy to the dough and contribute to its development. They also have a large influence on the dough rheological properties. Thus, in order to solve engineering problems associated with dough processing we should have an understanding and a quantitative description of how dough rheology can affect the process. Therefore, there is a need for tracking dough deformation and stress as dough travels through processing steps (e.g. augers, dough developer, metering pumps, forming dies). Computer simulation and modeling is an emerging alternative that is being used in this project for a better understanding on the effect of rheology on dough processing. A model based on a two dimensional flow has been completed. The model allows one to optimize the design of a coathanger die which is used for dough dividing operations. The coathanger design is used in the plastic industry for film sheeting. The model is currently being expanded to describe a 3D flow. (Papers A.8 and B.9)

**Status:** Active.

**12. Title: A Systematic Approach to Cereal Processes Development**

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

**Researchers:** Kelly Anne Ross, Ph.D. Student  
Carlos Corvalan, Visiting Scientist

**Collaborators:** Prof. L.P. Nolte, Department of Physics  
Prof. M.R. Okos, Dept. of Agriculture and Biological Engineering

**Sponsor:** Purdue Research Foundation

**Objectives:** The long term objective of this program is aimed to increase the consistency, quality and value of foods products made from grains, by providing the grain industry and grain processing research area with advanced knowledge of material properties and new or improved grain processing technologies. Specific objectives are:

1. To develop a mathematical model that allows one to predict the expansion of cereals by vapor induced puffing. The model is intended to be applied to several

cereal processing operations, which include: oven expansion, extrusion, bumping of cereals (e.g. rice).

2. To develop methodologies to measure physical properties of cereals which are relevant to puffing expansion. These properties include: rheological properties of intermediate products, diffusion coefficients and water absorption isotherms of cereals during processing.
3. To develop tools for the assessment of microstructural and rheological properties of finished products.

**Progress:** Processing of cereals involves operations such as mixing, heating, extrusion, puffing, and drying where raw materials are subjected to large stresses and deformations, and processing conditions, such as for example moisture and temperature, of different magnitudes. These operations have a large influence on the material rheological properties and the textural properties of the final product. The influence of raw material variability and processing conditions on the prediction of final product quality is one of the challenges and long term goal of the cereal processing industry. This project focuses on the rheological and physicochemical characterization of materials (raw material and final product). Material rheology is commonly utilized as a mean to characterize physicochemical changes undergone by raw materials due to processing (e.g puffing, flaking). These changes in general affect final product texture, functionality and nutritional properties.

It has been shown that the quality of porous foods is dictated by texture and the measurement of  $T_g$  has been noted in the literature to be a viable method of obtaining an index of texture and therefore an index of quality. DMTA is commonly used in food in food science research and is a preferred method of obtaining  $T_g$  measurements. Work in this project has shown that for both synthetic and biological porous specimens, the level of porosity affects the measurement of the  $T_g$ . Therefore, the effect of porosity should be acknowledged when discussing  $T_g$  measurements (Paper B.8).

**Status:** Active.

**13. Title: Identification of Causes of Stickiness of Dough**

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

**Researchers:** Stephen Christanto, M.S. Student  
Jaeyong Shim, Ph.D. Research Associate

**Sponsor:** Available for sponsorship

**Objective:** The objective of this work is to develop fundamental rheological methods to evaluate stickiness of dough. In particular the effect of milling conditions on the stickiness and rheological properties of dough is investigated.

**Progress:** Rheological properties of dough are determined using a Dynamic Mechanical Thermal Analyzer (DMTA) and a controlled stress rheometer. Stickiness of dough samples is determined with a Universal Testing Machine (Sintech), which is also used to measure the extensional properties of the dough samples. Damaged starch analysis and

NMR relaxometry are also performed to examine starch structure, water mobility changes, and their relationship with dough stickiness.

**Status:** Active.

- 14. Title: Acoustic Resonance Viscometry**  
**P.I.:** O.H. Campanella  
**Researcher:** Behic Mert  
**Sponsorship:** Available for Sponsorship

**Objective:** The long-term aim of the proposed research is to develop an in-line viscometer for foods based on the principle of acoustic resonance. To accomplish this objective, we intend to achieve the following specific objectives: (1) Develop and expand the relevant portions of acoustic theory that describe the interrelationships between the rheological and acoustical properties of foods through numerical modeling and simulation, (2) construct a bench-top viscometer that uses the principle of acoustic resonance to measure shear and extensional properties of liquid foods.

**Progress:** Relevant theory to predict the attenuation of sonic and ultrasonic waves in a liquid media has been adapted to the bench top viscometer. Appropriate instrumentation has been set to generate pressure waves and determine their attenuation. Experimental evidence is clearly showing that shear viscosity of liquids can be determined from the attenuation of the pressure waves at moderate frequencies. Results are also showing that if the frequency is increased at the ultrasonic level the extensional viscosity of liquid foods can be determined.

**Status:** Active.

- 15. Title: Design of a Novel Oil-expeller for the Processing of Soybeans**  
**P.I.:** O.H. Campanella, A. Sumali  
**Researcher:** Zabidin Zamzuri, M.S. Student  
**Sponsorship:** Malaysia Government

**Objective:** Design of a novel extrusion type oil-expeller for the processing of soybeans

**Progress:** This project has two phases. The first phase is related to the determination of rheological properties of soybeans that are relevant to their processing for the production of oil. The second phase of this project will deal with the design of a prototype to be used for research and scale-up purposes.

**Status:** Active.

- 16. Title: A study on the Ultrasonic and Rheological Properties of Dough During Fermentation.**  
**P.I.** O.H. Campanella  
**Researcher:** Suyong Lee  
**Collaborators:** Professor Laura Pirak Nolte, Department of Physics

**Objectives:** (1) Investigation on the shear and extensional rheological properties of dough (2) Ultrasonic characterization (velocity, attenuation) of dough. (3) Correlation of ultrasonic properties of dough with its rheological properties during fermentation.

**Progress:** As a novel and promising method to investigate the quality of dough, an ultrasonic technique is being developed and applied. The mechanical properties of dough are related to several factors such as water content, mixing time, and resting time, which have a great influence on the ultrasonic properties of dough. This study is focused on the characterization of the ultrasonic properties of dough and their correlation with the rheological properties of dough during fermentation. Results of this research are relevant to dough processing and have potential for on-line measurements.

**Status:** Active.

**17. Title: Energy Analysis of the Performance of Cereal Flaking Rolls.**

**P.I.** O.H. Campanella and M.R. Okos

**Researcher:** Leon Levine

**Collaborators:** C.M Corvalan and J.D. Reid

**Objectives:** Flaking of agricultural products is a widely used but poorly understood process. The process produces a final product of unique quality and texture that is extremely difficult to duplicate by any other process. The goal of this study is to develop a mathematical model that can describe the flaking process. The information developed in this project will be of long term value not only to researchers investigating the effect of processing on flaked product quality, but also to users and manufacturers of flaking equipment. Results of this research will also provide a method to predict the effect of shear on the overall quality of flaked products.

**Progress:** A model that describes the flow of Non-Newtonian power-law fluids during calendering of finite sheets has been developed. Unlike the classical calendering model in which the sidewise flow is neglected, the model presented in this work takes into account both lengthwise and sidewise flow. Results of the model were validated by measuring the width increase of a calendered polymeric material over a range of feed thicknesses, widths, gaps, and roll speed on two sheeters of different radius. Electrical power used to drive the rolls was measured and found to be correlated with certain processing parameters, viz., roll gap and roll speed. Fairly good results were obtained when the model results were compared with experimental data.

**Status:** Active.

**18. Title: Branched Polysaccharides in the Gellan Family**

**P.I.:** R. Chandrasekaran

**Researcher:** W. Bian, Ph.D. Student

**Sponsor:** Available for sponsorship

**Objective:** Determination of the molecular morphology of I-886

**Progress:** The three-dimensional structure of I-886, also known as RMDP17, in its sodium salt form has now been determined. The polymer adopts a gellan-like double helix. Two

RMDP17 helices are packed antiparallel in a trigonal unit cell. They are held together by sodium ions between their carboxylate groups and hydrogen bonds via water molecules. The disaccharide side units, (1→6)-linked to every anionic tetrasaccharide repeat of the main chain, further promote favorable interactions between the helices.

**Status:** Active. A paper on the final results for I-886/RMDP17 is in press (Paper B.12).

**19. Title: Junction Zone Details in Carrageenan Gels**

**P.I.:** R. Chandrasekaran

**Researcher:** Srinivas Janaswamy, Ph.D. Research Associate

**Sponsor:** Available for sponsorship

**Objective:** Determination of the architecture of ι-carrageenan helices and role of monovalent and divalent cations on gel properties.

**Progress:** Our good diffraction patterns obtained from (a) the sodium salt and (b) the calcium salt of iota-carrageenan have now been fully analyzed. In both cases, we confirmed the molecular structure to be a 3-fold, right-handed, half-staggered, double helix of pitch about 26 Å (first proposed in 1974). Three carrageenan helices are present (two up and one down) in a trigonal unit cell, stabilized mainly by water molecules and cations. The latter are directly involved in linking the peripheral sulfate groups. There are specific differences in the cation-mediated interactions between the two structures which suggest that the junction zones in carrageenan gels would be stronger in the presence of calcium than sodium. The structural results are consistent with the observed gelation properties.

A paper (Paper A.14) has been published on the sodium form. A paper on the calcium form (Paper B.14) is in press.

**Status:** Active.

**20. Title: Structure of Beijerin**

**P.I.:** R. Chandrasekaran

**Researcher:** W. Bian, Ph.D. Student

**Objective:** Determination of the structure-function relationship in bejieran.

**Progress:** The (1→3)-linked bacterial polysaccharide with an acidic trisaccharide repeat forms a 2-fold sinuous helix. Using X-ray data recorded from a well oriented and polycrystalline specimen of the sodium form, the three-dimensional structure has now been determined. Two helices are located in a monoclinic unit cell in an antiparallel fashion. The helices in the lattice are stacked tightly to form a thick sheet such that adjacent sheets associate via a network of sodium ions and water molecules trapped between them. The architecture of sodium bejieran in the solid state explains neatly the observed film-forming properties.

**Status:** Completed (Thesis E.1). A paper (Paper B.13) is in press.

**21. Title: Relationship Between Texture and EPS Content During Yogurt Formation**

**P.I.:** P. Cornillon

**Researcher:** Michelle Rzonca, M.S. Student

**Sponsor:** Available for sponsorship

**Objectives:** (1) Determination of the kinetics of yogurt fermentation by rheological and NMR methods. (2) Qualitative and quantitative characterization of the production of EPS during yogurt fermentation.

**Progress:** The formation of yogurt is characterized by fermentation of milk using active bacteria. These bacteria produce exopolysaccharides that tend to play a role in the overall texture and rheology of the final yogurt.

**Status:** Completed (Thesis E.7). A manuscript is in preparation.

**22. Title: Importance of Glass Transition on Storage Stability of Frozen Foods**

**P.I.:** P. Cornillon

**Researcher:** Suyong Lee, Ph.D. Student

**Sponsor:** Purdue Research Foundation, and World Food Logistics Organization

**Objectives:** (1) Determination of the glass-transition temperature of frozen foods. (2) Evaluation of physical property changes above and below the glass-transition temperature.

**Progress:** The stability of frozen foods during storage is dependent on the temperature in which the food product is stored and, hence, on its physical state. This project is focused on understanding the relationship between storage temperature and time and physical property changes.

**Status:** A manuscript has been submitted to Journal of Food Science (Paper C.9). Another is in preparation.

**23. Title: Kinetics of Osmotic Dehydration of Foods**

**P.I.:** P. Cornillon

**Researcher:** Melanie Budiman, Ph.D. Research Associate

**Objectives:** (1) Dehydration of fruits by osmotic dehydration. (2) Analysis of the diffusion of water and solutes through foods using MRI. (3) Quantification of water or solute uptake over time.

**Progress:** Osmotic dehydration is dependent on factors such as temperature, concentration of osmotic solution, contact time, nature of food product, etc. It is difficult to predict and measure the kinetics of water and solute migration in and out of the food being dehydrated. MRI provides a non-invasive and non-destructive capability to analyze the osmotic dehydration of foods over time. Water and solutes distribution will be mapped during the process.

**Status:** Completed.

**24. Title: Water States in Wheat Flour Doughs**

**P.I.:** P. Cornillon

**Researcher:** Yong-Ro Kim, Ph.D. Student

**Objectives:** (1) Determination of the states of water in wheat flour doughs as influenced by mixing and resting using NMR and dielectric measurements. (2) Correlation of water mobility to dough structure and rheology.

**Progress:** The degree of mixing of dough and its resting time influence how water interacts with gluten and starch. In addition, upon heating, dramatic rheological changes which are strongly related to water mobility occur. Analytical techniques like NMR, DETA, and rheology are being used in coordination to characterize the states of water and the internal structure and texture of dough.

**Status:** Completed (Thesis E.5). Paper A.15 was published.

**25. Title: Three-component Complex Among Starch, Protein, and Free Fatty Acids**

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

**Researcher:** M. Maladen, M.S. Student

**Sponsor:** Available for sponsorship

**Objective:** Determine unique functional properties and chemical aspects of a 3-component complex previously identified in our laboratory.

**Progress:** We previously (G. Zhang, Ph.D. thesis) identified a soluble 3-component complex involving amylose, free fatty acid, and soluble protein that resulted in a 2-3 fold increase in RVA cooling stage paste viscosity. A number of properties of the complex were also characterized: its approximate molecular weight is between 1 and 10 million daltons, free fatty acid binds both to the protein and amylose, and the complex is stabilized by disulfide bonding and electrostatic forces. The ratios of components were optimized and the complex was isolated in about 90% purity. In the past year, it was found that its temperature of formation is 60-70°C curing cooling; and stability studies showed solubility at room temperature to 10 days dissolution of the complex as ionic strength is increased, and pH stability down to pH 3. Recent preliminary studies show its potential as a soluble carrier of hydrophobic compounds.

**Status:** Active.

**26. Title: Investigation of the Basis of the Slowly Digesting Starch Characteristic of Cooked Sorghum Foods**

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

**Researcher:** B. Bugusu, Ph.D. Student

**Sponsor:** U.S. Agency for International Development/INTSORMIL

**Objective:** Investigate the origin of the slowly digesting starch characteristic of sorghum-based foods to find ways of increasing/decreasing digestion rates.

**Progress:** Sorghum foods that include the thick pastes/porridges eaten in West and East Africa and flat breads of India are known, both from scientific study and anecdotal evidence, to have comparably poor starch digestibility as well as poor protein digestibility. We have done significant work on the protein digestibility aspect of sorghum grain, and in this study have focused on starch digestion rate, partly as it relates to protein digestibility. Flours from normal and high protein-digestibility mutant sorghum genotypes and common maize and rice were digested using  $\alpha$ -amylase. With no protease pretreatment, starch digestion rates of all sorghum flours were less than that of maize and rice. However, following digestion with pepsin for 30 min, starch digestion rates of the high protein-digestibility mutant flour starches was nearly equal to that of maize or rice, while starch digestibility of normal sorghum genotypes remained low. Therefore, the slowly digesting starch characteristic of cooked sorghum flours appears to be linked to its poor protein digestibility. Improvements in starch digestibility in the mutant flours will be tested in sorghum-based infant weaning foods that would be suitable for use in sorghum-growing regions of Africa.

**Status:** Active.

**27. Title: Localization and Influence of Granule-Associated Proteins on Starch Behavior**

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

**Researcher:** X.Z. Han, Ph.D., Research Associate

**Collaborators:** J.N. BeMiller, J. Gray

**Objective:** Investigation of location of internal- and surface-associated proteins on starch granules and their possible affect on gelatinization behavior.

**Progress:** In this final year of the project, confocal laser scanning microscopy was used with the dye 3-(4-carboxybenzoyl)quinoline-2-carboxaldehyde to visualize proteins in gelatinized ghost structures and in channels of native starch granules. The dye is useful for this purpose as it only fluoresces when covalently bound to protein, thereby eliminating the necessity of thoroughly washing the dye out of the sample. Gelatinized ghost structures were found to be enriched with protein, presumably granule-bound starch synthase, leading to the speculation that protein is involved in maintaining ghost structure. Proteins were also found to line the channels of native corn starch. Protein-lined channels were also noted in starch granules in cross-sections of developing corn endosperm. Digestion with protease (thermolysin) removed channel proteins. Further studies are in progress to identify this protein. (Papers B.20, B.21, B.22, C.11, and C.12; Thesis E.4)

**Status:** Active.

**28. Title: Investigation on New Approaches to Produce Slowly Digesting Starches**

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

**Researcher:** X.Z. Han, Ph.D., Research Associate

**Sponsor:** Indiana 21<sup>st</sup> Century Research Fund

**Objective:** The goal of this project is to investigate and develop new methods of producing slowly digesting starches that have acceptable functionality.

**Progress:** Part of the impetus of this work was our previous and ongoing study, (Project 19) of the slow digestibility characteristic of cooked starch of sorghum flour, and the indication that extrinsic factors may also play a role in starch digestion rate. In this study, a number of approaches are being tried with the aim of attempting to develop ways to control starch digestion rates.

Initially, a range of different treatments were proposed to slow starch digestibility in a cooked product. These treatments were: 1) coating of cereal starches with gums, 2) coating of starch with gums plus an amylase inhibitor (cycloheptaamylose), 3) crystallization of debranched starch followed by annealing. Using an  $\alpha$ -amylase-based digestion assay, digestibilities of cooked normal and high-amylose (70% amylose) starches were slowed by about 30% and 35%, respectively, using treatment 3. Other studies to increase viscosity and gelation of these latter slowly digested starches are under way, as well as investigation of how to use extrinsic compounds, such as protein, to create slow-digesting starches.

**Status:** Active.

**29. Title: Investigation of Means to Improve Starch Digestibility of Sorghum Grain for Animal Feed Use**

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

**Researcher:** B. Suhendra, M.S. student

**Sponsor:** Pacific Seeds Ltd/Advanta

**Objective:** Determination of variability in raw starch digestibility among sorghum grain genotypes and its basis.

**Progress:** Sorghum grain has somewhat lower protein and starch digestibility when used as animal feed. Its comparably low starch digestibility, in particular, is a factor in its usage for ruminants and monogastric animals, and often necessitates preprocessing of the grain to increase energy availability. In this ongoing study, we are testing the hypothesis that sorghum genotypes, both normal and mutant lines, that have relatively rapid digesting protein will correspondingly have faster digesting starch. A range of sorghum genotypes was selected consisting of low to high *in vitro* digestibility normal lines and a number of high protein digestibility mutant lines (ranging in endosperm hardness). In initial studies using an  $\alpha$ -amylase-based assay, sorghum flours that were treated directly with  $\alpha$ -amylase showed digestion rate patterns in the same ranking as protein digestibility. Further studies are in process on the effect of protease predigestion of flours and investigation on the affect of amylose content on raw starch digestibility.

**Status:** Active.

**30. Title: Understanding the Basis of Variability in US Rice Quality through Studies of Genotypic and Environment-Induced Variation in Starch Structure**

**P.I.:** B.R. Hamaker  
**Researcher:** A. Aboubacar, Ph.D., Research Associate  
**Sponsor:** The Rice Foundation

**Objective:** Determination of the variability in amylopectin fine structure/molecular weight and amylose content/molecular weight among rice genotypes and same genotypes grown in different locations, and their relationships to cooked whole grain and flour gel textures.

**Progress:** In this second year of the project, studies focused on locational variation in rice quality found within genotypes. Variability in cooked whole grain and flours due to location where the rice is grown or due to year is a significant problem for processors who use rice and rice ingredients. Yet, the basis for these differences is not well understood. In this study, starch properties, including amylose content/average molecular weight and amylopectin fine structure/average molecular weight, were determined in nine rice genotypes grown in Missouri, Arkansas, and Texas. Textural properties of cooked whole grain rice and flour and starch gels were also measured. Texture differed most in rice genotypes grown in Missouri, where amylose content was also consistently higher than in Arkansas and Texas. Using a multi-angle laser light scattering detector coupled with size-exclusion chromatography and refractive index detection, amylopectin and amylose average molecular weight was shown to differ in the same genotypes grown in different locations. Some differences due to location were also noted for amylopectin branch chain profiles. Thorough data analysis is currently being done to evaluate relationships among parameters.

**Status:** Active.

**31. Title: Adhesiveness and Cohesiveness as Related to Glucan Fine Structure and Size**

**P.I.:** B.R. Hamaker  
**Researcher:** B. Prado, M.S. student  
**Sponsor:** Available for sponsorship

**Objective:** Investigation of the relationship of dextrin size and branched structure on the degree of stickiness and cohesiveness in foods.

**Progress:** Previous studies in our laboratory (Aboubacar, Ph.D. Thesis; Mix, M.S. Thesis) showed that low-molecular-weight branched glucans contributed to the stickiness characteristic of a processed product (sorghum couscous) and starch gels. The origin of this component was found to be fragmentation of amylopectin during grain milling. In the present study, two methods have been used to obtain branched fragments of different molecular weights. In the first, corn starches conditioned to different moisture contents were ball-milled and soluble fragmented amylopectin was analyzed by intermediate pressure size-exclusion chromatography. Three fragmented fractions were identified. In the second method, a commercial low DE maltodextrin was fractionated by molecular weight differences using an ethanol precipitation procedure. Three fractions differing in molecular weight were obtained using this procedure that were of higher molecular weight than the above fractions. Therefore, a fairly wide molecular weight range of soluble branched glucans were obtained for further studies on their contribution to stickiness and cohesiveness in a starch paste/gel matrix.

**Status:** Active.

**32. Title: Edible Pre-Coating of Popcorn for Increased Shelf Life and Improved Microwave Popping Performance**

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

**Researcher:** A. Tandjung

**Sponsor:** State of Indiana Value-Added Program

**Objectives:** Determination whether coating of popcorn can be used to increase shelf life. Investigation of the structural and chemical basis of unpopped kernels in microwave popcorn.

**Progress:** A range of coatings were applied to popcorn, and using an accelerated storage system, popcorn was tested for potential reduction in number of unpopped kernels and overall popping performance. Moisture loss was determined for coated popcorn, as well as on a collection of popcorn hybrids, both during storage and during microwaving. Studies are continuing on determining strategies to improve microwave popcorn performance.

**Status:** Active.

**33. Title: Starch-Gum Complex Formation Using Heat Treatments**

**P.I.** S.-T. Lim, Visiting Professor

**Researcher:** J.A. Han, Visiting Student

**Sponsor:** WCCR, Korea University.

**Objective:** Developing new food hydrocolloid-starch composites by heat treatments.

**Progress:** Waxy maize (native and hydroxypropylated) and potato starches were impregnated with ionic gums (sodium alginate, CMC, and xanthan; 1% based on starch solids) and heat-treated in a dry state for 2 or 4 h at 130°C. Effects of the heating on paste viscosity (RVA) and clarity (light transmittance) were examined. Treatment with sodium alginate and CMC raised the paste viscosity of native and hydroxypropylated waxy maize starches, but decreased that of potato starch. Xanthan provided the most substantial changes in paste viscosity among the tested gums. It heavily restricted granular swelling of the waxy maize starches, but increased swelling of potato starch granules. Dry heating raised the paste viscosity of all the starch-gum mixtures tested, except the potato starch-alginate mixture. The final viscosity at 50°C was raised in all other starches by approximately 500 – 1,000 cP by this treatment. The paste of waxy maize starch-gum mixtures become opaque and shorter textured by the heat treatment, regardless of the gum type, whereas potato starch-gum mixtures did not show any obvious change in paste rheology or clarity. Ionic gums could function as crosslinking agents via formulation of graft copolymers through ester formation. Due to the presence of like charges, potato starch was less reactive than waxy maize starch. It is concluded that this simple heating process with ionic gums could be used as a potential physical modification method for starch. (Paper C.1)

**Status:** Active.

**34. Title: Changes in Chain Profile of Corn Starches During Extensive Heating and Stirring**

**P.I.:** S.-T. Lim, Visiting Professor

**Researcher:** J.A Han, Visiting Student

**Sponsor:** WCCR, Korea University

**Objective:** Examination of chain profiles of corn starches of different amylose contents and the effects of aqueous heating and stirring (autoclaving and boiling) for sample dissolution.

**Progress:** Corn starches of different amylose contents (waxy, normal and Hylon VII) were debranched with an isoamylase, freeze-dried, and then subjected to extensive heat treatment in water (autoclaving and stirring in boiling water) for chain profile analysis using aqueous size-exclusion chromatography (SEC). Chain length was measured using multi-angle-laser-light scattering (MALLS) and RI detectors connected to an HPLC column (Superdex H75). Number-average chain length (CL<sub>n</sub>) was determined by the Nelson-Somogyi method. During autoclaving (121°C, up to 60 min) or boiling-stirring (up to 3 days), thermal degradation as well as aggregation of starch chains occurred. These tendencies were more significant with longer chains; high-amylose corn starch was most susceptible to the heat treatment. The optimum heating conditions for debranched waxy corn starch for SEC was found to be autoclaving 15 min and then boiling 1 h, but debranched normal corn starch required at least 24 h of boiling-stirring after autoclaving to complete chain dissolution. It was not possible to determine optimum heating conditions for debranched high-amylose starch because of the significant changes in the amylose. For reproducible SEC analysis, using an alkaline solution or DMSO for sample dissolution is strongly recommended.

**Status:** Active.

**35. Title: Modeling and Analysis of Disordered Crystalline Assemblies**

**P.I.:** R.P. Millane

**Researchers:** J.L. Eads, Ph.D. Student

A. Goyal, Ph.D. Student

**Sponsor:** NSF

**Objective:** Develop and apply methods for modeling and analyzing diffraction from disordered crystalline systems.

**Progress:** Crystalline polymer and other macromolecular assemblies often exhibit disorder in the way that the molecules pack together. Two commonly used models of disorder are the paracrystal and the perturbed lattice. We have shown for one-dimensional systems that, with an appropriate generalization of the paracrystal model, the two models are essentially identical. It is observed experimentally that crystallites that are more disordered are generally smaller. We have shown that an interpretation of the “spiral paracrystal” accounts quantitatively for this phenomenon. Current work is concerned

with studying x-ray diffraction properties of the “ideal paracrystal”, a model commonly used to describe the disordered packing of polymer molecules in two dimensions.

We are also studying the disordered myosin lattice that occurs in some types of muscle. We have begun developing a statistical model of this interesting kind of disorder. Future work will involve completing and validating this model, and studying its x-ray diffraction properties. (Paper A.22; Thesis E.3)

**Status:** Active.

**36. Title: Methods to Locate Guest Molecules in Crystalline Polymer Fibers**

**P.I.:** R.P. Millane

**Researcher:** S. Baskaran, Ph.D. Student

**Sponsor:** NSF

**Objective:** Improve algorithms used to determine positions and interactions of counterions and solvent molecules in polysaccharide crystal structures.

**Progress:** The functional properties of polysaccharides (gelling, thickening, etc.) often depend on cooperative intermolecular interactions between molecules that sometimes involve bound counterions and water molecules. Crystal structures of polysaccharides together with these guest molecules are used to characterize these interactions. We have developed methods to locate guest molecules that better take into account the nature of the x-ray data available from crystalline polymer fibers.

**Status:** Completed.

**37. Title: Monte Carlo Simulation of Polymers in Solution**

**P.I.:** R.P. Millane

**Researcher:** A. Goyal, Ph.D. Student

**Sponsor:** Available for sponsorship.

**Objective:** Use Monte Carlo simulations to help understand relationships between chemical structure and rheology of polysaccharide solutions and gels.

**Progress:** Approach is to use statistical mechanical simulations of coarse-grained polymer models to examine solution and network properties, and thence rheological properties, as a function of polysaccharide primary structure parameters, such as frequency and length of interacting segments.

**Status:** Active.

**38. Title: Effect of Protein-Surfactant Interactions on Interfacial Rheology and Emulsion Stability**

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

**Researcher:** Allison Ray, M.S. Student

**Sponsor:** Available for sponsorship

**Objectives:** (1) Investigation of the effect of composition of mixtures of  $\beta$ -lactoglobulin and Tween 20 and pH on interfacial rheology at the air-water interface and foam stability. (2) Investigation of the effect of composition of mixtures of  $\beta$ -lactoglobulin and Span 80 and pH on interfacial rheology at the oil-water interface and emulsion stability.

**Progress:** In many food and pharmaceutical formulations, a mixture of surfactant and protein is employed. Surfactants reduce interfacial tension, thereby facilitating formation of emulsions and foams with reduced energy consumption. Proteins, on the other hand, form a cohesive interfacial adsorbed layer, thus providing shelf life through enhanced interfacial rheology, as well as steric repulsion between adsorbed layers. It is important to understand the competitive adsorption of proteins and surfactants at interfaces as it relates to emulsion/foam stability. This research focuses on  $\beta$ -lactoglobulin and its interactions with Tween 20, a water-soluble surfactant, at the air-liquid interface and Span 80, an oil-soluble surfactant, at the liquid-liquid interface. Competitive adsorptions of  $\beta$ -lactoglobulin (BLG)/sorbitan monooleate (Span 80) and BLG/polyoxyethylene sorbitan monolaurate (Tween 20) at oil-water and air-water interfaces, respectively, were characterized through measurements of interfacial rheology, interfacial tension, drop coalescence, and emulsion/foam stability at pH 5.5 and pH 7. Interfacial rheology, interfacial tension, and drop coalescence experiments were conducted at n-tetradecane-water and air-water interfaces with 0.005-wt % BLG. In the presence of Span 80 and Tween 20, BLG was displaced from the interface, leading to reductions in interfacial viscosity and elasticity. At high molar ratios of surfactant, interfacial viscosity and elasticity reflected those of an interface comprised of a purely surfactant layer. Interfacial tension was significantly reduced upon the addition of surfactant. Coalescence time for a single oil droplet introduced into BLG solution at the n-tetradecane-water interface was longest when there was no surfactant present in the oil phase. In contrast, coalescence of a single air bubble at the air-water interface with an adsorbed layer of Tween 20/BLG mixtures increased for larger Tween 20/BLG molar ratios and was longest for an interface comprised purely of Tween 20. Coarsening of soybean-oil-in-water emulsions stabilized by BLG, as well as mixtures of BLG/Span 80 of different molar ratios, were compared using absorbance measurements. Foams prepared at pH 7 with a mixture of BLG and Tween 20 became less stable at higher molar ratios of Tween 20/BLG; foams that were prepared with Tween 20 alone exhibited the greatest instability. Emulsions and foams prepared at pH 5.5 were highly unstable; this instability may be attributed to the reduction in electrostatic repulsion between adsorbed layers near the isoelectric point (pH 5.5) of BLG. The critical film thickness inferred from thin film stability analysis of imposed thermal perturbations was found to be much smaller than those calculated from experimental measurements of coalescence time at the air-water interface. Therefore, it was concluded that mechanical perturbations were important in drop coalescence measurements.

**Status:** Active.

39. **Title:** Effect of Conformation on Foaming Properties of Proteins  
**P.I.:** G. Narsimhan  
**Researcher:** Zebin Wang, Ph.D. Student  
**Sponsor:** Available for sponsorship

**Objectives:** (1) Modification of the secondary and tertiary structures of globular proteins by heating at different temperatures and times and by manipulation of pH in the range of 2 to 9. (2) Characterization of interfacial shear and dilatational rheological properties (elasticity and viscosity) of air-water interface with adsorbed layer of these proteins. (3) Investigation of the effect of physical modification of proteins on the drainage and stability of foams from the experimental measurement of evolution of liquid holdup profile and foam collapse. (4) Development of a mathematical model for drainage and stability of foam accounting for colloidal forces.

**Progress:** Interfacial shear elasticity and viscosity of adsorbed layer of  $\beta$  casein at air-water interface was measured using Camtel interfacial rheometer. Interfacial dilatational viscosity of adsorbed layer of  $\beta$  casein at air-water interface was inferred using a pulsating bubble tensiometer. Foams were formed by whipping air into  $\beta$  casein solution using a food processor. The evolution of liquid holdup profile of a draining foam was measured using magnetic resonance imaging (MRI). These measurements indicated a lag time before the formation of a separate aqueous layer at the bottom of the draining foam. A mathematical model is being developed to describe the evolution of liquid holdup profile in a draining foam accounting for liquid drainage in Plateau borders. The model could also predict the equilibrium liquid holdup profile. The model predictions are being compared with the data.

**Status:** Active.

**40. Title: Ecotype-strain specificity in *S. meliloti*-*M. truncatula* interactions**

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

**Researcher:** T. Ojanen-Reuhs, Ph.D. Research Associate  
Safi Diallo, undergraduate student

**Sponsor:** Grant proposal in review at NSF

**Collaborator:** G. Walker (MIT)

**Objectives:** (1) To dissect the biochemical and genetic basis for compatible *S. meliloti*-*M. truncatula* symbiosis. (2) Structural characterization of specific oligosaccharide signal-molecules. (3) Genetic analysis of the plant response to compatible and incompatible symbiotic infection.

**Progress:** Legumes may enter into a symbiotic association with gram-negative, nitrogen-fixing bacteria. Molecular signals are instrumental in the establishment of symbiosis, and bacterial extracellular polysaccharides (EPS) promote the infection process in *Sinorhizobium meliloti*-*Medicago sativa* (alfalfa) symbiosis. Purified EPS shows signal activity at  $10^{-11}$  M. This project focuses on ecotype-strain specificity in *S. meliloti*-*M. truncatula* interactions. *M. truncatula* is used because it is closely related to alfalfa and it is the subject of a worldwide genomics project. *S. meliloti* strains NRG185 and NRG34 infect *M. truncatula* ecotype A17 (compatible), but fail to establish nitrogen-fixing nodules on ecotype A20 at 21 days post infection (incompatible). Importantly, the phenotypes are reversed with *S. meliloti* strains NRG247 and Rm41. We have determined that infectivity is EPS-dependent, indicating that different ecotypes of *M. truncatula* have different structural requirements for oligosaccharide signal activity; and we have found a correlation between the EPS oligosaccharide structure and the host specificity of the bacterial strain.

**Status:** Active.

**41. Title:** *hrp*-Dependent phase shift in *Sinorhizobium fredii*-soybean symbiosis

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

**Researcher:** T. Ojanen-Reuhs, Ph.D. Research Associate  
Elisa Halim, undergraduate student

**Sponsor:** NSF

**Collaborators:** H. Krishnan (University of Missouri), W. Broughton (University of Geneva)

**Objectives:** (1) Determination of structural changes associated with phase shift and *nol* mutations in *S. fredii*. (2) Identification of the avirulence factor from wild-type *S. fredii*. (3) Structural characterization of two novel polysaccharides that appear to be “bacteroid-specific” surface components. These specific objectives are part of a broader goal of increasing the knowledge base concerning the bacterial cell surface, and the infection and differentiation processes which lead to bacteroid development and nitrogen fixation.

**Progress:** Soybeans are an important part of worldwide agriculture, and nitrogen fixation contributes significantly to the production of this legume crop plant. Wild-type *Sinorhizobium fredii* USDA257 is unable to infect the roots of most cultivars of North American soybeans; however, a mutation in the *nolXWBTUV* gene region, which shares homology with the *hrp* genes of plant pathogens, extends the host range of *S. fredii* USDA257 to many domestic cultivars. Importantly, the presence of wild-type strain USDA257 in the inoculum acts to block the infection of the new hosts by *nol* mutants, indicating that the parent strain produces a restrictive factor (avirulence factor). Preliminary findings have shown that *nol* mutations directly affect the expression of bacterial cell-surface polysaccharides. We have determined that many of the changes associated with the mutations are similar to the phase shift changes wild-type cells undergo during infection. We have also determined the structure of two novel polysaccharides that appear to be “bacteroid-specific” surface components of *S. fredii* USDA257, and which are abnormally expressed in *nol* mutants. We have raised antibodies against these polysaccharides, and bacteroids from many host plants will be probed to determine the nature and distribution of the products. In addition, the project has been expanded to include another strain of *S. fredii* and the closely related *Sinorhizobium* sp. NGR234, which is the subject of a European genomics project.

**Status:** Active.

**42. Title:** Harpin Z-cell wall association in *Pseudomonas syringae* pathogenesis.

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

**Researcher:** T. Ojanen-Reuhs, Ph.D. Research Associate  
Lisa Hartano, undergraduate student

**Sponsor:** None

**Objectives:** (1) Purification of intact harpin Z to further characterize harpin interactions with the cell wall. (2) Determination of cell wall components that are involved in harpin Z association.

**Progress:** Harpin Z is a protein that is produced by the plant pathogenic bacterium *Pseudomonas syringae* pv. *Syringae*, a major cause of disease in vegetable crops. Harpin Z secretion is *hrp*-dependent. It elicits the hypersensitive response (HR) in incompatible plants and is required for pathogenesis in compatible hosts. The ultimate target of harpin Z is unknown. However, past studies have shown that it binds to the plant cell wall. We have developed an efficient protocol to isolate the protein in large quantities and have performed preliminary analyses to determine the cell wall component that binds harpin Z. We have found that harpin Z associates with a plant cell-wall component present in a pectic preparation, and that the cell-wall component is EPG sensitive, suggesting that it is homogalacturonan or rhamnogalacturonan II. The project also includes the study of a harpin-like product from *Xanthomonas campestris*, the cause of black rot of tomato and pepper plants.

**Status:** Active.

## PUBLICATIONS AND OTHER SCHOLARLY ACTIVITIES

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

#### BeMiller

1. **Kerry C. Huber** and **James N. BeMiller**, Location of sites of reaction within starch granules, *Cereal Chem.*, 78 (2001) 173-180.
2. **Jonathan A. Gray** and **James N. BeMiller**, Accessibility of starch granules to fatty acylamides, *Cereal Chem.*, 78 (2001) 236-242.
3. **James N. BeMiller**, Polysaccharides, in *Encyclopedia of Life Sciences*, MacMillan Reference Limited, London, 2001.
4. **James N. BeMiller**, Plant cell walls: economic significance, in *Encyclopedia of Life Sciences*, Macmillan Reference Limited, London, 2001.
5. **James N. BeMiller**, Classification, structure, and chemistry of polysaccharides in foods, in *Handbook of Dietary Fiber*, S.S. Cho and M.L. Dreher, eds., Marcel Dekker, New York, 2001, pp. 603-611

#### Campanella

6. M. Budiman, R. Stroshine, and **O.H. Campanella**, Stress relaxation and low field proton magnetic resonance studies of cheese analogs, *J. Text. Studies*, 31 (2000) 477-498.
7. **Oswaldo H. Campanella** and Micha Peleg, Theoretical comparison of a new and the traditional method to calculate *Clostridium botulinum* survival during thermal processing, *J. Sci. Food Agric.*, 81 (2001) 1069-1076.
8. **J.D. Reid**, **C.M. Corvalan**, **L. Levine**, **O.H. Campanella** and M.R. Okos, Sheeting/rolling of finite width sheets. Estimation of final sheet width and the forces and power exerted by the rolls, *Cereal Foods World*, 46 (2001) 63-69.
9. Bernhard Hoffner, **Oswaldo H. Campanella**, Maria G. Corradini, and Micha Peleg, Squeezing flow of a highly viscous incompressible liquid pressed between slightly inclined lubricated wide plates, *Rheol. Acta*, 40 (2001) 289-295
10. L.A. Zimmer, T.A. Haley, and **O.H. Campanella**, A comparative study on the performance of selected in-line viscometers to test the viscosity of Newtonian and non-Newtonian fluids, *J. Text. Studies*, 32 (2001) 75-103.
11. M.J. Grossman, S.M. Mezsick, D.R. Howard and **O.H. Campanella**, "Stratus" soy protein foamed dessert, Patent Appl. P-01049, 2001.

Also paper A.17.

### Chandrasekaran

12. **S. Arnott, W. Bian, R. Chandrasekaran, and B. Manis**, Lessons for today and tomorrow from yesterday – The structure of alginic acid, *Fiber Diffraction Rev.*, 9 (2000) 44-51.
13. **R. Chandrasekaran** and G. Stubbs, Fibre diffraction, *in* International Tables for Crystallography, Volume F. Crystallography of Biological Macromolecules, M.G. Rossmann and E. Arnold, eds., Kluwer Academic Publishers, Dordrecht, 444-450, 2001.
14. **S. Janaswamy and R. Chandrasekaran**, Three-dimensional structure of the sodium salt of iota-carrageenan, *Carbohydr. Res.*, 335 (2001) 181-194.

### Cornillon

15. **Yong-ro Kim and Paul Cornillon**, Effects of temperature and mixing time on molecular mobility in wheat dough. *Lebensm. Wiss. Technol.*, 34 (2001) 417-423.
16. **Peggy Walter and Paul Cornillon**, Influence of thermal conditions and presence of additives on fat bloom in chocolate, *J. Amer. Oil Chem. Soc.*, 78 (2001) 927-932.

### Hamaker

17. **B.A. Bugusu, O. Campanella, and B.R. Hamaker**, Improvement of sorghum-wheat composite dough rheological properties and breadmaking quality through zein addition, *Cereal Chem.*, 78 (2001) 31-35.
18. **Adam Aboubacar, John D. Axtell, Cha-Ping Huang, and Bruce R. Hamaker**, A rapid protein digestibility assay for identifying highly digestible sorghum lines, *Cereal Chem.*, 78 (2001) 160-165.
19. **X.Z. Han and B.R. Hamaker**, Amylopectin fine structure and rice starch paste breakdown. *J. Cereal Sci.*, 34 (2001) 279-284.
20. **B.R. Hamaker** and B.A. Larkins, Maize food and feed: a current perspective and consideration of future possibilities, *in* Transgenic Crops, Marcel Dekker, New York, 2001.

### Millane

21. **R.P. Millane**, X-ray fiber diffraction analysis, *in* International Tables for Crystallography, Vol. B. U. Shmueli, ed., Kluwer Academic Publishers, International Union of Crystallography, 2001. 466-481.
22. **J.L. Eads and R.P. Millane**, Diffraction by the ideal paracrystal, *Acta Crystallogr.*, A57 (2001) 507-517.

### **Narsimhan**

23. **M. Cornec, D.A. Kim, and G. Narsimhan**, Adsorption dynamics and interfacial properties of  $\alpha$ -lactalbumin in native and molten globule conformation at air-water interface, *Food Hydrocoll.*, (2001) 303-313.
24. **G. Narsimhan and P. Goel**, Drop coalescence during emulsion formation in a high pressure homogenizer for tetradecane in water emulsions stabilized by sodium dodecyl sulphate, *J. Colloid Interface Sci.*, 238 (2001) 420-432.
25. M. Neogi and **G. Narsimhan**, On Oswald ripening of oil drops in a micellar solution, *Chem. Eng. Sci.*, 56 (2001) 4225-4231.

### **Reuhs**

26. E. Kiss, A. Kereszt, F. Barta, S. Stephens, **B.L. Reuhs**, A. Kondorosi, and P. Putnoky, The rkp-3 K antigen gene region of *Sinorhizobium meliloti* Rm41 contains strain-specific genes that determine polysaccharide structure and size range, *Mol. Plant-Microbe Interact.*, 14 (2001) 1395-1403.
27. S.C. Kachlany, S.B. Levery, J.S. Kim, **B.L. Reuhs**, L.W. Lion, and W.C. Ghiorse, Structure and carbohydrate analysis of the exopolysaccharide capsule of *Pseudomonas putida* G7, *Environ. Microbiol.*, 3 (2001) 774-784.

## **B. Papers and Book Chapters in Press**

### **BeMiller**

1. **Xiaohong Shi and James N. BeMiller**, Effects of food gums on viscosities of starch suspensions during pasting, *Carbohydr. Polym.*
2. **Duy-Phong Pham-Huu, Yonas Gizaw, James N. BeMiller**, and Ladislav Petruš, New synthesis of 1,4-dideoxy-1,4-imino-D-galactitol from D-glucose propane-1,3-diyl dithioacetal, *Tet. Lett.*, 43 (2002).
3. **Xiaohong Shi and James N. BeMiller**, Aqueous leaching of derivatized amylose from hydroxypropylated common corn starch granules, *Starch/Stärke*, 54 (2002).
4. **Jonathan A. Gray and James N. BeMiller**, Bread staling: molecular basis and control, *Comp. Rev. Food Sci./Food Safety*, 1 (2002).

### **Campanella**

5. **O.H. Campanella** and M. Peleg, Squeezing flow viscometry for liquid and semiliquid foods, *Critical Rev. Food Sci. Technol.*
6. P.P. Singh, D.E. Maier, and **O.H. Campanella**, Effect of temperature and moisture on dynamic viscoelastic properties of soybeans, *Trans. ASAE*

7. **L. Levine, C.M. Corvalan, O.H. Campanella,** and M.R. Okos, A model describing the calendering of finite width sheets, *Chem. Eng. Sci.*
8. **K.A. Ross, O.H. Campanella,** and M.R. Okos, The effect of porosity on glass transition measurement, *Intern. J. Food Prop.*
9. **J.D. Reid, O.H. Campanella, C.M. Corvalan,** and M.R. Okos, The influence of power-rheology on flow distributions in coathanger manifold, *Polym. Eng. Sci.*
10. A.J. Carr, P.A. Munro, and **O.H. Campanella,** Effect of added monovalent or divalent cations on the rheology of sodium caseinate solutions, *Intern. Dairy J.*
11. **O.H. Campanella,** P.X. Li, **K.A. Ross,** and M.R. Okos, The role of rheology in extrusion, *in* Engineering and Food for the 21st Century, J. Welti-Chanes, G.V. Barbosa-Canovas, and J.M. Aguilera, eds., Technomic Publishing.

Also papers B.20 and B.21.

#### **Chandrasekaran**

12. **W. Bian, R. Chandrasekaran,** and M. Rinaudo, Molecular structure of the rhamnan-like exopolysaccharide RMDP17 from *Sphingomonas paucimobilis*, *Carbohydr. Res.*
13. **W. Bian, R. Chandrasekaran,** and K. Ogawa, X-ray structure analysis of the sodium salt of beijerin, *Carbohydr. Res.*
14. **S. Janaswamy** and **R. Chandrasekaran,** Effect of calcium ions on the organization of iota-carrageenan helices: an X-ray investigation, *Carbohydr. Res.*
15. **R. Chandrasekaran, S. Janaswamy,** and **W. Bian,** Interactions of cations and water molecules with polysaccharide helices in oriented fibers and correlation with rheological properties, *Polym. Preprints.*

#### **Cornillon**

16. **J.E. Shin, P. Cornillon,** and L.C. Salim, The effect of centrifugation on agar/sucrose gels, *Food Hydrocoll.*
17. P. Walter and **P. Cornillon,** Influence of foreign fat migration on fat bloom in chocolate, *J. Am. Oil Chem. Soc.*
18. N. Dawkins, J. Gager, **P. Cornillon,** and **Y.R. Kim,** A. Howard, and O. Phelps, Comparative studies on the physicochemical properties on hydration behavior of oat gum and oat trim in meat-based patties, *J. Food Sci.*

#### **Hamaker**

19. **B.A. Bugusu,** B. Rajwa, and **B.R. Hamaker,** Interaction of maize zein with wheat in composite dough and bread as determined by confocal laser scanning microscopy, *SCANNING*

20. **X.Z. Han, O.H. Campanella**, H. Guan, P.L. Keeling, and **B.R. Hamaker**, Influence of maize starch granule-associated protein on the rheological properties of starch pastes. Part I. Large deformation measurements of paste properties, *Carbohydr. Polym.*
21. **X.Z. Han, O.H. Campanella**, H. Guan, P.L. Keeling, and **B.R. Hamaker**, Influence of maize starch granule-associated protein on the rheological properties of starch pastes. Part 2. Dynamic measurements of viscoelastic properties of starch pastes, *Carbohydr. Polym.*
22. **X.Z. Han** and **B.R. Hamaker**, Location of starch granule-associated proteins revealed by confocal laser scanning microscopy (Rapid Communication), *J. Cereal Sci.*
23. **Y.P. Lin, A. Aboubacar**, B.E. Zehr, and **B.R. Hamaker**, Corn dry-milled grit and flour fractions exhibit differences in amylopectin fine structure and gel texture, *Cereal Chem.*
24. L.F. Dowling, C. Arndt, and **B.R. Hamaker**, Economic viability of high digestibility sorghum as feed for market broilers, *Agronomy J.*

#### **Narsimhan**

25. N. Pongcharoenkiat, **G. Narsimhan**, R.T. Lyons, and S.L. Hem, The effect of surface charge and partition coefficient on the chemical stability of solutes in O/W emulsions. *J. Pharm. Sci.*
26. **G. Narsimhan**, Surface Phenomena, in *Encyclopedia of Life Support Systems*, Barbosa-Canovas, ed.

#### **Reuhs**

27. G.R.O. Campbell, **B.L. Reuhs**, and G.C. Walker, *S. meliloti* LPS is required for bacterial differentiation into the bacteroid form, *Proc. Natl. Acad. Sci. USA.*

## **C. Manuscripts Submitted (in review process)**

#### **BeMiller**

1. **S.-T. Lim, J.-A. Han, H.S. Lim**, and **J.N. BeMiller**, Modification of starch by dry heating with ionic gums, *Cereal Chem.*

#### **Campanella**

2. M. Peleg, M.D. Normand, and **O.H. Campanella**, Estimating microbial inactivation parameters from a single survival curve obtained under varying conditions – The linear case. *Food Research International.*

#### **Cornillon**

3. **A. Gonera** and **P. Cornillon**, Gelatinization study of starch/gum/sugar systems by using DSC, NMR and CLSM, *Starch/Stärke*

4. **P. Cornillon**, Imaging and relaxation study of the osmotic dehydration of grapes, *Mag. Reson. Imag.*
5. P. Veillard, **P. Cornillon**, and R. Strohshine, Effect of soluble and insoluble solids on NMR properties of orange juice, *J. Sci. Food Technol.*
6. K.H. Jung, R.L. Strohshine, P.M. Hirst, and **P. Cornillon**, Effects of watercore and internal browning on low field (5.35 MHz) proton magnetic resonance measurements of T<sub>2</sub> values of whole apples, *J. Sci. Food Agric.*
7. **M. Budiman**, R.L. Strohshine, and **P. Cornillon**, Moisture measurement in cheese analog using stretched and multiexponential models of the magnetic resonance T<sub>2</sub> decay curve, *J. Dairy Res.*
8. **J.H. Auh**, **Y.R. Kim**, **P. Cornillon**, and K.H. Park, Cryoprotecting mechanism of highly concentrated branched oligosaccharides, *Int. J. Sci. Food Technol.*
9. **S. Lee**, **P. Cornillon**, and **Y.R. Kim**, Physical properties and water distribution in frozen foods: Effect of freezing rate and storage conditions, *J. Food Sci.*
10. **P. Cornillon**, Analysis of spin-spin relaxation data of foods with the stretched exponential model, *Mag. Reson. Imag.*

#### **Hamaker**

11. **X.Z. Han** and **B.R. Hamaker**, Association of starch granule proteins with starch ghosts and remnants revealed by confocal laser scanning microscopy, *Cereal Chem.*
12. **X.Z. Han** and **B.R. Hamaker**, Partial leaching of granule-associated proteins from rice starch during alkaline extraction and subsequent pasting, *Starch/Stärke*

### **D. Papers Presented at Meetings and Conferences and Invited Public Lectures**

1. **James N. BeMiller**, Influence of starch granule architecture on granule reactivity, Brigham Young University, February.
2. **O.H. Campanella**, Comparison of a new and the traditional method to calculate microbial survival and quality changes during thermal processing of food products, 1<sup>st</sup> International Congress in Food, Chemical and Environmental Engineering, Universidad de las Americas, Mexico, March.
3. **O.H. Campanella**, A systematic approach to cereal process development, 1<sup>st</sup> International Congress in Food, Chemical and Environmental Engineering, Universidad de las Americas, Mexico, March.
4. **James N. BeMiller**, Overview of food hydrocolloid use, 11<sup>th</sup> World Congress of Food Science and Technology, Seoul, Korea, April.

5. **Seung-Taik Lim, Jung-Ah Han, and James N. BeMiller**, Heat treatments of starch-gum mixtures for viscosity modification, 11<sup>th</sup> World Congress of Food Science and Technology, Seoul, Korea, April.
6. **P. Cornillon**, Thermal analysis of foods. A review, Annual Meeting of the Canadian Thermal Analysis Society, Ottawa, Canada, May.
7. **G. Narsimhan**, Protein adsorption and foam stabilization, Society of Industrial Microbiology, St. Louis, June.
8. **James N. BeMiller**, Chemical methods of food carbohydrate analysis, Institute of Food Technologists annual meeting, New Orleans, June.
9. **James N. BeMiller**, (Forum) From graduation to the 'real world': industry and student perspectives, Institute of Food Technologists annual meeting, New Orleans, June.
10. **P. Cornillon**, MDSC analysis of carbohydrate systems, Institute of Food Technologists annual meeting, New Orleans, June.
11. **X.Z. Han, O. Campanella, and B.R. Hamaker**, Location of granule bound starch synthase (GBSS) in starch granules and significance of GBSS on the rheological properties of starch pastes, Institute of Food Technologists annual meeting, New Orleans, June.
12. **K.A. Ross, O.H. Campanella, and M.R. Okos**, The effect of porosity on glass transition measurement, Institute of Food Technologists annual meeting, New Orleans, June.
13. **James N. BeMiller**, Commercial polysaccharides: History and structure-functional property relationships, Gordon Research Conference on Chemistry of Polysaccharides, Mount Holyoke College, South Hadley, MA, July.
14. M. Budiman, R. Stroshine, **O. Campanella, P. Cornillon**, and S. Nielsen, Modeling of low field proton magnetic resonance T2 decay curves for the purpose of moisture and fat content measurement of cheese analog, American Society of Agricultural Engineers annual meeting, Sacramento, CA, July.
15. C.G. Aguirre, K. Haghighi, **C.M. Corvalan, and O.H. Campanella**, A stochastic finite element methodology for analysis of coffee beans during roasting, American Society of Agricultural Engineers annual meeting, Sacramento, CA, July.
16. **Duy-Phong Pham-Huu, Yonas Gizaw, James N. BeMiller**, and Ladislav Petruš, New stereospecific synthesis of C- $\alpha$ - and  $\beta$ -D-arabinofuranosylformaldehyde dithioacetals, American Chemical Society, Chicago, August.
17. **D. Kim and G. Narsimhan**, Effect of physical modification on interfacial properties of beta lactoglobulin at oil-water interface. American Chemical Society, Chicago, August.
18. **M. Cornec, D. Kim and G. Narsimhan**, Effect of conformation on adsorption of alpha lactalbumin and beta lactoglobulin at air-water interfaces, American Chemical Society, Chicago, August.

19. **Jung-Ah Han, James N. BeMiller, Bruce Hamaker, and Seung-Taik Lim**, Heating effect on chain structure of debranched corn starches in water, American Association of Cereal Chemists annual meeting, Charlotte, NC, October.
20. **Seung-Taik Lim, Jung-Ah Han, and James N. BeMiller**, Reaction of ionic gums with starch during dry heat treatment, American Association of Cereal Chemists annual meeting, Charlotte, NC, October.
21. **Xiaohong Shi and James N. BeMiller**, Effects of food gums on viscosity of starch suspensions during their pasting, American Association of Cereal Chemists annual meeting, Charlotte, NC, October.
22. **Kerry C. Huber and James N. BeMiller**, Location of sites of reaction within starch granules, American Association of Cereal Chemists annual meeting, Charlotte, NC, October.
23. **Jonathan A. Gray and James N. BeMiller**, Method to study modification reactions of corn starch granules using reflectance confocal microscopy, American Association of Cereal Chemists annual meeting, Charlotte, NC, October.
24. **S. Christanto, J. Shim, O.H. Campanella, and M.R. Okos**, Effect of processing on the stickiness properties of dough, American Association of Cereal Chemists annual meeting, Charlotte, NC, October.
25. **X.Z. Han and B.R. Hamaker**, Detection of starch granule-associated proteins and their association with pasted starch granule structures, American Association of Cereal Chemists annual meeting, Charlotte, NC, October.
26. **M. Maladen and B.R. Hamaker**, Optimizing the formulation of a novel three-component complex, American Association of Cereal Chemists annual meeting, Charlotte, NC, October.
27. **X.Z. Han and B.R. Hamaker**, Leaching of starch granule-associated proteins during alkali-extraction of rice starch, American Association of Cereal Chemists annual meeting, Charlotte, NC, October.
28. **A.S. Tandjung, J.S. Marks, and B.R. Hamaker**, Effect of added zein on glass transition temperature and physical properties of starchy extrudates, American Association of Cereal Chemists annual meeting, Charlotte, NC, October.
29. **C.P. Huang and B.R. Hamaker**, Protein bodies and immunolocalization of alpha- and gamma-kafirins of developing wild type and high protein digestibility mutant sorghum lines, American Association of Cereal Chemists annual meeting, Charlotte, NC, October.
30. **James N. BeMiller**, Those wonderful, useful carbohydrates, Northwest Central Ohio Section, American Chemical Society, Ada, OH, November.
31. **James N. BeMiller**, Applications of biopolymers, Columbus Section, American Chemical Society, Columbus, OH, November.
32. **James N. BeMiller**, Applications of biopolymers, Upper Ohio Section, American Chemical Society, Marietta, OH, November.

33. D. Kim and **G. Narsimhan**. Effect of conformation on interfacial properties of beta lactoglobulin, American Institute of Chemical Engineers annual meeting, Reno, NV, November.
34. **A. Ray** and **G. Narsimhan**. Effect of beta lactoglobulin-surfactant interactions on interfacial rheology, emulsion and foam stability, American Institute of Chemical Engineers annual meeting, Reno, NV, November.
35. **J.D. Reid**, **C.M. Corvalan**, **O.H. Campanella**, and M.R. Okos, Rheology of calendering in the food industry, American Institute of Chemical Engineers annual meeting, Reno, NV, November.
36. **C.M. Corvalan**, **O.H. Campanella**, and M.R. Okos, Density changes in non-Fickian high temperature drying, American Institute of Chemical Engineers annual meeting, Reno, NV, November.
37. **B. Mert**, **O.H. Campanella**, and H. Sumali, Determination of viscosity of liquids using vibration, American Institute of Chemical Engineers annual meeting, Reno, NV, November.
38. L.A. Rozzi, M.R. Okos, and **O.H. Campanella**, Effect of the power rheological properties on the granulation process, American Institute of Chemical Engineers annual meeting, Reno, NV, November.

## **E. GRADUATE DEGREES AWARDED**

1. **W. Bian**, Ph.D. X-Ray fiber diffraction study on industrially important polysaccharides.
2. **Anna Marie D. Duldulao**, M.S. Effect of hydroxypropylation on the rate of acid-catalyzed hydrolysis of granular starches.
3. **Jonathan Eads**, Ph.D. Diffraction by Disordered Crystalline Materials.
4. **Xian-Zhong Han**, Ph.D. Influence of starch structure and starch granule-associated proteins on rheological properties of starch pastes.
5. **Yong-Ro Kim**, Ph.D. Physicochemical properties of hard wheat flour dough influence by processing.
6. **Bridget Ryan Manis**, Ph.D. Modification of granular starch with protein.
7. **Michelle Rzonca**, M.S. Relationship between textural and physicochemical properties of yogurt during fermentation.

## **RECOGNITIONS, AWARDS, HONORS, AND ACTIVITIES**

1. **J.N. BeMiller** completed his term as President of the American Association of Cereal Chemists and then became the Chair of the AACC Board of Directors in October.
2. **Jonathan Gray** is President of the IFT Student Association.
3. **Joshua Reid** earned both an AACC scholarship and a Purdue doctoral fellowship.
4. **Joshua Reid** completed a term as Chair of the AACC Student Division in October.
5. **Jonathan Stapley** is now the Chair of the AACC Student Division.

