SUSTAINING MEMBERS

(Members of the 1999 Industrial Advisory Board)

Cerestar USA

Kellogg Company

Kraft Foods

Nestlé

Penford Corporation

Procter & Gamble

ASSOCIATE MEMBER

Matsutani Chemical Industry

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Director's Statement - 1999

1999 was an exciting, productive, and successful year for the Whistler Center. But as Winston Churchill said, "Success is never final". That is our motto. Last year's annual report highlighted the addition of Dr. Campanella to our faculty and rheology to our capabilities. Late in 1999, the Department of Food Science obtained approval and began a search for a carbohydrate polymer chemist. This position is being added because we foresee a need for structural characterization of carbohydrates from plants that have been genomically modified. These carbohydrates may include starches, cell wall materials such as pectins, and perhaps new polysaccharides. So we continue to move forward and build on our unique strengths.

The Whistler Center primarily does what universities do best -- generation and dissemination of knowledge. Our industrial partners and our Focus Groups are an important part of this process. As a university research center, teaching and learning are our primary mission. As a center of graduate education, we carry out our mission largely via research projects in which students learn by doing, whether the project be primarily theoretical or experimental. Work done by students and post-doctoral associates under faculty direction, whether at the bench or at the computer, generates data, models, and prototypes. Data and theory are then combined to generate new knowledge and new tools. In this way, we meet other objectives, which are to give our industrial partners a worthwhile return on their investment in us and with them to achieve common goals and meet common needs. We have a spectrum of relationships with our partners, but we can separate them into two general types: those involved with generation of fundamental knowledge and confidential projects. The former are the subject of this annual report. The latter (not reported) usually are brief and limited in size.

Technology of all kinds is changing rapidly, and we in higher education must both lead and respond to these changes. As the rate at which science can be done becomes more and more rapid and there is more and more understanding, learning must become more and more efficient. And we must provide more service to our students and our industrial partners, something we have had to find ways to do with less in recent years.

In a nutshell, in addition to producing young scientists, the Whistler Center provides access to ideas, knowledge, and talented academic researchers, in fact top scientists specializing in biopolymers (especially, but not exclusively, polysaccharides) and low-molecular-weight carbohydrates of practical interest. Ideas are created and knowledge generated via industry partnerships. It is obvious from our sustained growth that we are meeting the needs of industry in these areas. 1999 was a year of progress and productivity as we are proud to tell you about in this report. The report also gives a glimpse of our continuing efforts via reports on ongoing projects. When reading them, keep in mind that Whistler Center faculty also does some research related to structure and functionality of biopolymers other than carbohydrates. **We invite companies that produce or use carbohydrates to join us and share our excitement and research output.**

J.N. BeMiller

Summary of Major Research Accomplishments - 1999

Starch and Cereals:

Two studies (sorghum couscous and corn masa; projects 35 and 36, respectively) relating amylopectin fragmentation to stickiness were either completed (masa) or nearly completed (couscous) by Dr. Hamaker's group. Highly significant correlations relating the amount of a low-MW branched fraction and stickiness were found in both cases. Investigation into the fraction origins showed that high shear produced at the milling step, either during masa milling or flour milling, produced the soluble branched components. In the case of flour milling, the amount of the low-MW branched starch fraction correlated to starch damage. Further studies are in progress to determine the degree of fragmented starch generation with different types of milling and its impact on gel texture.

Amylopectin fine structure of different rice varieties was examined and found to correlate significantly to RVA paste viscosity breakdown. The proportion of debranched, long linear chains was negatively correlated with breakdown; and conversely, the proportion of short chains was positively correlated. While it does not prove a causal effect of amylopectin fine structure on paste breakdown, the data does suggest that gelatinized swollen granules may be stabilized or strengthened by longer branched structures.

A large three-component soluble complex consisting of amylose, free fatty acid, and soluble protein was identified by HPSEC (project 34). The complex was stabilized by intermolecular disulfide bonds and electrostatic forces. DSC analysis showed a competitive binding of free fatty acids and protein or amylose. Moreover, the presence of soluble protein increased the solubility of the amylose-free fatty acid complex. The three-component interaction caused a notable increase in RVA cooling stage paste viscosity similar to that produced by some surfactants.

Dr. Whistler continues development of uses for "porous starch" and has an interest in hemicelluloses which are beginning to show strong uses in pharmaceuticals. He is seeing a developing interest in banana starch that can be commercially produced from the approximate one-fourth of the banana crop that is too small in size or is damaged and is thrown away, creating an environmental problem. Production is simple, requiring only grinding bananas in bisulfite solution at the proper pH, screening, and centrifugation. Thus, small, low-cost starch factories are possible, with likely financial help from local governments concerned with waste disposal. Raw banana starch is 93% resistant starch that is non-digested in the small intestine, which is of benefit in some applications.

Most of the projects of Dr. BeMiller are based on the hypothesis that higher value starch products can be made using allowable reagents and levels of addition by controlling where modification occurs within granules. This work naturally involves a better understanding of granule structure. Results from research of his students and postdoctoral associates have confirmed that the radial, tube-like channels of corn and sorghum starch granules vary in depth and that channels exist in granules at all developmental stages of the plant and, thus, are not artifacts (project 13).

A study of the relationship of reagent size to penetration into common corn, waxy maize, and potato starch granules confirmed the heterogeneity of granules from any source and that the polymer molecules in the area surrounding the hilum are less densely packed (project 13). Using fluorescent fatty acyl amides, it was found that the limits for granule exclusion were at C_{14} and C_{12} for common corn starch and potato starch swollen in water, respectively. The type of salt used to inhibit swelling under industrial etherification conditions was found to affect granule swelling. It has also been determined that certain molecules far larger than previously thought are capable of penetrating the granule matrix (project 13).

Hydroxypropylated common corn, waxy maize, potato, and tapioca starch granules were treated with aqueous acid at room temperature. Preliminary results show that the more substituted areas are more susceptible to acid-catalyzed hydrolysis, confirmed the heterogeneous nature of starch granules, that there are definite differences between the susceptibility of modified and unmodified starches from different sources to acid-catalyzed hydrolysis, show that hydroxypropylated starches undergo depolymerization more rapidly than do unmodified starches, and show that there are only slight differences between hydrolysis of starches modified in the presence of different salts to the same MS value (project 23).

Water Relationships and Thermal Events:

Dr. Cornillon and his students have worked on understanding water interactions with basic food ingredients (sugars, gums, and lipids) in various foods. Accomplishments include the elucidation of water interactions in dough as influenced by mixing and resting time (project 6), detecting and measuring fat migration and fat bloom occurrence in chocolate (project 8), cryoprotection characteristics of a highly branched oligosaccharide (project 9), and an investigation of the gelatinization of starch as influenced by additives like sugars and gums (project 10).

Interfacial Phenomena:

Dr. Narsimhan and his students have studied the dynamics of adsorption of α-lactalbumin at pH 7 and pH 2 at air-water interface (project 3). The secondary and tertiary conformations of α-lactalbumin at pH 7 and pH 2 were compared. CD spectra indicated that the secondary conformation of α-lactalbumin at the two pH values were more or less the same, whereas the tertiary conformation of the protein was completely destroyed at the acidic pH. Loss of tertiary conformation at pH 2 also resulted in a two-fold increase in surface hydrophobicity, leading to an increase in surface activity in spite of a higher electrostatic energy barrier to adsorption. Whereas the spread monolayer of α-lactalbumin at air-water interface at pH 7 tended to unfold over time, leading to a larger area per molecule at the interface, the molecular area decreased with time at pH 2 due to the formation of loops and tails. This is believed to be due to the increased flexibility of α-lactalbumin at pH 2. The increased flexibility at pH 2 is further evidenced by a smaller hysteresis area between the compression and expansion cycles of the spread monolayer compared to that at pH 7. Even though α-lactalbumin at pH 2 was more surface active than it was at pH 7, the interfacial shear elasticity and shear viscosity were found to be smaller at the acidic pH.

Experiments were conducted in a Rannie laboratory-scale, single-stage homogenizer for tetradecane in water emulsions stabilized by sodium dodecyl sulfate (SDS) (project 1). Coalescence rate constants were inferred from the short-time evolution of number concentration of drops in the stirred vessel of a recirculating system subjected to a negative step change in applied homogenizer pressure. The residence time of the emulsion in the homogenizer was evaluated from the analysis of radial turbulent flow between disks. The step-down homogenizer pressure, drop size, dispersed phase fraction, SDS concentration, and ionic strength were varied. The coalescence rate constant was found to be higher for higher homogenizer pressures, smaller drop sizes, higher dispersed phase fractions, and lower SDS concentrations and was insensitive to variations in ionic strength. The average coalescence time of doublets, evaluated from analysis of the random process of intervening continuous-phase film thickness, was dependent on the energy barrier for coalescence due to the net repulsive force (net effect of colloidal repulsive and turbulent attractive forces). The predicted overall coalescence rate constant was found to be larger for larger turbulent energy dissipation rates, smaller surface potentials, larger drop sizes, and smaller ionic strengths at constant surface potentials and larger ionic strengths at constant surface charge densities and agreed fairly well with the experimental data.

Molecular Structures and Properties of Hydrocolloids:

Dr. Narsimhan and his students have quantified the effect of steam sterilization on the rheology and molecular weight distribution of xanthan, Carbopol, guar gum, and HEC (project 2). For solutions of the three polysaccharides, the apparent viscosity was found to decrease upon autoclaving, the decrease being more pronounced at longer autoclaving times. For Carbopol, autoclaving resulted in an increase in the apparent viscosity. Circular dichroism spectra of xanthan indicated a transition from a helix to a random coil conformation upon autoclaving. Autoclaving of xanthan solution of low concentration resulted in a significant shift in the molecular weight distribution to smaller values due to the breakup of molecular aggregates. As expected, this decrease in the molecular weight was pronounced at longer autoclave times. At moderate xanthan concentration, however, there was negligible change in the molecular-weight distribution upon autoclaving, even though there was a significant decrease in the apparent viscosity. This is believed to be due to disentaglement of the polymer chains due to heating.

Dr. Millane and his students have continued their efforts to improve the methods by which x-ray diffraction data are analyzed to provide accurate and reliable structural information on complex polysaccharide and protein crystalline and semi-crystalline systems (projects 29-32). Applications to cellulose and proteins are underway (projects 28, 29, 32).

Dr. Chandrasekaran's paper (paper A.3) summarizes the structural features and their correlation with the functional properties of several industrially important polysaccharides. Further x-ray and molecular modeling studies to elucidate the precise molecular details of the branched polymers in the gellan family (project 25), the junction zones in alginate and pectin gels (project 26), and the influence of ions on the gelation of carrageenans (project 27) are underway.

Rheology:

Dr. Campanella and his students have worked on understanding the role that rheology plays in food processing and food texture evaluation. A project has been initiated to study the rheology of dough, its role in dough stickiness, and how it is influenced by processing conditions and flour characteristics. Another project initiated by Dr. Campanella's group is rheological characterization of extruded foams. The role of moisture, glass transition, and microstructure of the foam on the perceived texture is being investigated. A project related to mathematical modeling of dough flow through a dough divider has been started. The study focuses on the effect of dough rheology on the strain and pressures generated during flow with the aim of an optimum design of the divider. In another project, the fluid mechanics of the flaking process are being developed using computer modeling. The effect of estimated strain on material rheology and resulting product microstructure is also being investigated.

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James N. BeMiller
Professor

Starch granule structure, reactivity, and behavior. Chemical and genetic modification of starch. Structure-functional property relationships of polysaccharides. Modifications of polysaccharides. New plant and microbial polysaccharides. Mono- and disaccharide chemistry and modification. Light, confocal, and electron microscopy. Uses of carbohydrates in food and other industries. Pectin analysis.

Osvaldo H. Campanella
Assistant Professor

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
Professor

Conformational theory of biopolymers. Structure-function relationships and molecular structures of polysaccharides, nucleic acids, and polypeptides. Molecular architectures of polysaccharide-polysaccharide, protein-polysaccharide, protein-nucleic acid, and nucleic acid-drug interactions. Molecular graphics.

Paul Cornillon
Assistant Professor

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 of composition, constituents, and experimental conditions on. Freezing of foods (formation of ice crystals, stability of frozen foods, quality changes, freezing damage). Glass transition and mobility. DSC, DETA, cryomicroscopy, rheology.

Bruce R. Hamaker
Professor

Cereal chemistry and technology. Cereal starch and protein functionality and digestibility. Textural properties influenced by starch fine structure and interactions between starch and other food components. Use of immunological and microscopic techniques in quantitation and localization of specific cereal proteins in normal and mutant cereal genotypes. Appropriate methods of improving cereal utilization in developing countries. Cereal endosperm texture.

Rick P. Millane
Professor

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
Professor

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.

Roy L. Whistler
Distinguished Professor Emeritus

Chemistry, structure, design, and use of carbohydrates (sugars and polysaccharides) in medicine, foods, and nonfoods. Basic science and applications of carbohydrates. Starch. Reactions of carbohydrates. Systems for micro-transport of drugs, flavors, insecticides, etc.

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 in polysaccharide crystal systems.

Aditya Bindal earned a B.S. degree in Chemical Engineering from Indian Institute of Technology, Kharagpur. He joined Dr. Narsimhan's research group in August 1997 in the M.S. degree program, which he completed in 1999. He is now in the Ph.D. program. His research topic is effect of steam sterilization on the rheology of polymer solutions.

Wen Bian earned B.E. and M.S. degrees in food science and engineering from Ocean University of Quingdao, China. He joined Dr. Chandasekaran's group in the Fall of 1997 as a Ph.D. student. His research topic is structure-function correlations of polysaccharides.

Betty Bugusu joined Dr. Hamaker's group in January 1998 to pursue an M.S. degree. Betty comes from the Kenyan Agricultural Research Institute and received a B.S. degree from Egerton University in Kenya in 1991. She is a part of the USAID-funded INTSORMIL project and is working on a subproject to find ways to increase the functionality of sorghum proteins in composite flours. Betty received her M.S. degree in December 1999 and is continuing studies towards a Ph.D. degree.

Stephen Christanto obtained two B.S. degrees from Purdue University: Chemical Engineering (May 1998) and Food Process Engineering (May 1999). Stephen is originally from Indonesia, came to the States in 1992 to finish high school in Melbourne, FL and came to Purdue in 1994. As an undergraduate, Stephen did bioseparation research in the Chemical Engineering Department under the guidance of Dr. Linda Wang. Stephen joined Dr. Campanella's group for the M.S. program in Food Process Engineering in May 1999. His research deals with dough rheology and the causes of dough stickiness.

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 a M.S. student of Dr. BeMiller in June 1999. Her thesis project is a study of the pattern of acid-catalyzed hydrolysis of hydroxypropylated starch granules.

Jonathan L. Eads earned a B.A. degree, Cum Laude, in Physics from Central College, in Iowa. He was awarded an USDA National Needs Fellowship in 1995 and began study towards the Ph.D. degree in Dr. Millane's laboratory. His research project is concerned with modeling and analysis of disordered polymer systems. He expects to complete degree requirements in August 2000.

Parul Goel earned a B.S. degree in Chemical Engineering from Indian Institute of Technology, Bombay. She joined Dr. Narsimhan's research group in Fall 1997. Her M.S. research project involves studying the effect of proteins on coalescence of emulsions in a high-pressure homogenizer.

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 network structure and viscoelastic properties of polysaccharide gel systems.

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. 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. His M.S. thesis project involved studying granular access to fatty acids of various chain lengths in different starches. His Ph.D. research is a study of the effects of reaction conditions on derivatization of starch granules.

Xianzhong Han obtained B.S. and M.S. degrees in plant biology from Hangzhou University in 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. His Ph.D. research involves a study of the relationship of starch granular and fine structure to functionality.

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 an Co-Op program with the USDA in their Fermentation Biochemistry Research Unit. Dennis joined Dr. Narsimhan's group in 1997 and completed several research projects, some of which have been presented to industry and various conferences. After interning with Kraft Foods over the summer, he returned to Dr. Narsimhan's research group to pursue his masters' degree in Food and Bioprocess Engineering. His research is involved with modification of model food proteins and studying changes in their interfacial and physicochemical properties.

Yong-Ro Kim joined Dr. Cornillon's group in January 1998. He earned a B.S. degree in Food Science & Technology from Seoul National University, Korea, then worked at Korea Institute of Science and Technology for one year before entering the graduate program in Food Science. 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. His Ph.D. project is the characterization of low-moisture-content cereal products using rheological, dielectric, and NMR measurement techniques.

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 is now a Ph.D. student of Dr. BeMiller. Her Ph.D. thesis topic involves finding new, more natural ways to modify starch behaviors.

Michael Miklus obtained B.S. and M.S. degrees in Food Science from The Pennsylvania State University. He came to Purdue in July 1995 to pursue a Ph.D. degree and in May 1996 joined Dr. Hamaker's group. Mike's thesis research focused on the components and molecular interactions that are responsible for the cohesive, doughy structure of corn masa. Mike graduated with his Ph.D. degree in September and is now a research scientist at Kraft Foods, Inc.

Nadege Mix earned a B.S. degree in chemistry from University of Bowling Green, Ohio in May 1998 and joined Dr. Hamaker's group in August. Nadege is a native of France. Her M.S. work is on the origin and characterization of a low-molecular-weight, soluble, branched, starch component that has previously been shown to correlate with product texture.

Shashi Mohan joined Dr. Narsimhan's group in August 1993. He obtained a Bachelor of Technology degree in Agricultural Engineering from Indian Institute of Technology, Kharagpur. He completed M.S. degree requirements in July 1995. His thesis topic was drop coalescence in food emulsions. He is currently working toward a Ph.D. degree and continuing his studies of drop coalescence during formation of food emulsions.

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

Susan Reinwald received her B.S. degree in Food Science and Nutrition at Deakin University in Melbourne, Australia in 1998. She received a scholarship to complete a Master's degree at Purdue University as a student of Dr. Narsimhan. Her M.S. research project involves studying the effects of hydrocolloids in gelling systems.

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 a 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 for half a year. 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.

Michelle Rzonca earned a B.S. degree in Food Science from Purdue University and joined Dr. Cornillon's group in August 1999. Currently, she is the IFTSA Midwest Area Representative and next year will be the IFTSA Chapter of the Year competition chair. Her M.S. work deals with the texture of yogurt and using NMR and HPLC for evaluation.

Yezhou Sun has a B.S. degree in applied chemistry from Peking University and an M.S. degree in condensed matter physics from the Chinese Academy of Sciences. After a year of practical training in Kagawa Medical University, Japan, he joined Dr. Chandrasekaran's laboratory in the Fall of 1998 as a Ph.D. student. His research focuses on correlation of molecular morphology with the functional properties of polysaccharides.

Agung Tandjung graduated with a B.S. degree in Food Science from Purdue and joined Dr. Hamaker's group in an M.S. degree program in August 1998. Agung originally is from Indonesia and came to the U.S. in 1995 following a year-and-a-half of study in British Columbia. He is working on the role of corn zein protein in the functionality of breakfast cereal products.

V. Kurtis Villwock earned a B.S. degree in Food Science from the University of Illinois at Champaign/Urbana, then worked at Continental Colloids, Inc. before entering graduate school in August 1994 as a student of Dr. BeMiller. He completed M.S. degree requirements in the Spring of 1996. His M.S. thesis research was a study of the mechanisms of starch derivatization. Kurt then spent 14 months in the laboratory of Dr. Eliasson at the University of Lund, Sweden doing part of his Ph.D. research on starch-lipid interactions. The remainder of his thesis involved an improved method for measuring water sorption by starch granules and developmental aspects of starch granule channels. Kurt completed Ph.D. requirements in December and accepted a position with Penford Food Ingredients.

Jinfa Ying earned a B.S. degree in Food Science at Zhejiang Agricultural University, Hangzhou, P.R.C. and a M.S. degree in Food Commodity Science at Renmin University of China, Beijing. He joined Dr. Cornillon's group as a Ph.D. student in January 1998. His research focuses on applications of NMR techniques to food science with an emphasis on frozen foods.

Genyi Zhang joined Dr. Hamaker's group in August 1995. Genyi earned a B.S. degree in biology from Lanzhou University and an M.S. degree in genetics from the Institute of Genetics, Academia Sinica, Beijing. He first pursued an M.S. degree in Food Science, investigating starch digestibility. For his Ph.D. thesis, Genyi investigated an interesting 3-component interaction among amylose, free fatty acid, and soluble protein, and its effect on paste viscosity. He graduated in December 1999 and is currently looking for a position in the food industry or academia.

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, West Africa. His Ph.D. research project involved a study 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, is working as a post-doctoral Research Associate in Dr. Hamaker's lab, and is seeking employment.

Dr. Michel Cornec received his Ph.D. degree from the Department of Food Science at the University of Nantes, France. For his Ph.D. research, he investigated the rheological behavior of wheat gluten. He then pursued postdoctoral work at the Institute of Food Research, Norwich, England, where he investigated molecular interactions in absorbed layers formed from mixtures of proteins and surfactants at the oil-water interface in order to understand the mechanism of destabilization of emulsions. He joined Dr. Narsimhan's group in March 1996, studying competitive adsorption of proteins and food emulsifiers at the air-water interface. Dr. Cornec is now employed at Borden.

Dr. Linus Fonkwe joined Dr. Narsimhan’s group as a postdoctoral research associate in July, 1999. Dr. Fonkwe received his Ph. D. degree in Food Science from Purdue University under the guidance of Dr. R. K. Singh investigating the recovery and characterization of proteins from poultry processing byproducts. Prior to joining Dr. Narsimhan’s group, he was a postdoctoral research associate with Dr. J. D. Floros, then Dr. R. K. Singh. He is currently investigating the gelation of various systems and the behavior of soybean protein fractions in emulsion systems.

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 structure analysis of inorganic compounds containing barium, magnesium, and tantalum in single crystals and in 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.

Dr. Rakasi Kavitha joined Dr. BeMiller's laboratory in April 1996. Dr. Kavitha earned a Ph.D. degree from University of Mysore, India in 1993. Her thesis research topic was non-starch polysaccharides of sorghum. Before coming to Purdue, she did postdoctoral work on cereal arabinoxylans and xylanases under the supervision of Drs. H. Gruppen and A.G.J. Voragen of Wageningen Agricultural University, The Netherlands. At Purdue, she has been involved in a variety of projects involving starch and pectin chemistry and analytical techniques.

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.

Dr. Jacob van der Plas received the Ph.D. degree in chemistry from Leiden University, The Netherlands, in 1998. His Ph.D. research was concerned with theoretical and computational methods for solving small-molecule crystal structures. Dr. van der Plas joined Dr. Millane's group in June 1998. He is currently working on developing new computational algorithms for protein crystallography.

Dr. Xiaohong Shi joined our graduate program in 1992, after earning a B.S. degree in polymer physics from the Department of Applied Chemistry at 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 in May 1998. Her thesis project under the direction of Dr. BeMiller was self-supporting, edible films. She continues to investigate the chemistry and behaviors of starches using rheological and NMR techniques.

Dr. Qian Zhang joined Dr. Whistler's laboratory as a post-doctoral Research Associate in July, 1997. Dr. Zhang earned an M.S. degree in physical chemistry in 1990 from Fudan University, China with a thesis on a conductive polymer and its application. He completed the Ph.D. program in organic chemistry at the University of Louisville in May, 1997. His research topic was synthesis and bioassay of *C*-mannosides as bacterial anti-adhesion agents. Currently, he is working on starch modification.

VISITING STUDENTS, SCHOLARS, AND

SCIENTISTS

Joong-Hyuck Auh spent two months in Dr. Cornillon's laboratory as an exchange Ph.D. student from the Department of Food Science & Technology and Research Center for New Bio-Materials in Agriculture, Seoul National University, Korea where he obtained his M.S. degree in food chemistry in l995 and is enrolled in the Ph.D. program. In Dr. Cornillon's laboratory, his research activities were focused on a study of the cryoprotection of proteins by highly branched oligosaccharides (HIBOS) using NMR relaxometry.

Antje Gonera spent 6 months in Dr. Cornillon's laboratory as an exchange student from the Institute of Food Chemistry at the Technical University in Dresden, Germany, where she is a junior student under the supervision of Dr. Karl Speer. In Dr. Cornillon's lab, Antje is studying glass transition and gelatinization temperatures of starch mixtures with gums, sugars, and water using modulated DSC and isothermal NMR relaxometry. Her stay in the Whistler Center continues into 2000.

Professor **Kenji Okuyama**, Tokyo University of Agriculture and Technology, Japan was a Visiting Professor in Dr. Chandrasekaran's laboratory for a month in July. He was accompanied by three of his graduate students **Tatsuo Egawa**, **Masakazu Kanenari,** and **Yuji Tanaka**. During this visit, they conducted collaborative research on the x-ray structures of chitosan derivatives.

Peggy Walter spent 6 months in Dr. Cornillon's laboratory as an exchange student from ENSBANA, Dijon, France where she is a junior student in the Food Science and Biology department. In Dr. Cornillon's laboratory, her research activities were focused on fat bloom and fat migration characterization in chocolate samples using NMR and thermal analysis.

STAFF

Chia-Ping Huang
Cereals Lab
Research Assistant

Peg Purdue
Technician

Marilyn Yundt
Center Secretary

PROJECT SUMMARIES

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1. **Title:** **Effect of Processing Parameters and Formulation on the Formation of Food Emulsions in a High-pressure Homogenizer**

P.I.: G. Narsimhan
Researchers: Shashi Mohan, Ph.D. Student
Parul Goel, M.S. Student
Sponsor: USDA

Objective: (1) To study the effects of homogenizer pressure and food emulsion formulations on drop coalescence in a high-pressure homogenizer. (2) To propose a model for drop coalescence in a turbulent flow accounting for interdroplet colloidal forces.

Progress: Experiments were conducted in a Rannie laboratory-scale, single-stage homogenizer for tetradecane in water emulsions stabilized by sodium dodecyl sulfate (SDS). Coalescence rate constants were inferred from the short-time evolution of number concentration of drops in the stirred vessel of a recirculating system consisting of the homogenizer and a stirred tank when subjected to a negative step change in applied homogenizer pressure. The residence time of the emulsion in the homogenizer was evaluated from analysis of radial turbulent flow between disks. The step down homogenizer pressure was varied in the range of 20.7 to 48.3 MPa, the drop size in the range of 175 nm to 209 nm, the dispersed phase fraction in the range of 5% to 15%, SDS concentration in the range of 0.0033 to 0.25 weight%, and ionic strength in the range of 0.01 to 0.1M. The coalescence rate constants were found to be in the range of 3.59×10^{-17} to 2.43×10^{-16} m^3 s^{-1}. The coalescence rate constant was found to be higher for higher homogenizer pressures, smaller drop sizes, lower dispersed phase fractions, and lower SDS concentrations and was insensitive to variations in ionic strength. The proposed model views drop coalescence as a two-step process consisting of formation of a doublet due to drop collisions followed by coalescence of the individual droplets in a doublet due to drainage of the intervening film of continuous phase under the action of colloidal and random turbulent forces. The average coalescence time of the doublet, evaluated from the analysis of the random process of intervening continuous phase film thickness, was dependent on the energy barrier for coalescence due to the net repulsive force (net effect of colloidal repulsive and turbulent attractive forces). The predicted overall coalescence rate constant was found to be larger for larger turbulent energy dissipation rates, smaller surface potentials, larger drop sizes, smaller ionic strengths at constant surface potentials, and larger ionic strengths at constant surface charge densities. Model predictions agreed with inferred experimental values of coalescence rate constants for drop sizes within the range of observed size distributions

Status: Open.

2. **Title:** **Effect of Steam Sterilization on Rheology of Polymer Solutions**
P.I.: G. Narsimhan
Researchers: Aditya Bindal, M.S. Student
Michel Cornec, Ph.D., Research Associate
Sponsor: NSF Research Center for Pharmaceutical Processing

Objective: To investigate the effect of steam sterilization on the rheology of polymer solutions through the characterization of changes in rheological properties, conformation, and molecular weight distribution due to steam sterilization.

Progress: Polymers are used in food and pharmaceutical formulations to provide thickening, stability, binding, consistency, sedimentation, film formation, and other functionalities. Apparent viscosity, storage and loss moduli, circular dichroism, and size-exclusion chromatography were employed to characterize changes in rheological properties, conformations, and molecular weight distributions of polymers upon steam sterilization. Xanthan gum, Carbopol, guar gum, and hydroxyethyl cellulose (HEC) were chosen for the above-mentioned study. The apparent viscosity of xanthan solution (0.025 wt % - 0.5 wt %), guar gum solution (0.1 wt % - 0.4 wt %), and HEC (2 wt %) were found to decrease upon autoclaving. The decrease was greater for greater autoclaving times. However, the viscosity of Carbopol 940 increased upon autoclaving, this increase being higher for low pH values and lower concentrations. Intrinsic viscosity decreased for xanthan from 10.82 dL/g to 3.78dL/g upon autoclaving for 15 min. Circular dichroism (CD) spectra showed a change in the conformation of xanthan in solution upon autoclaving. The proportion of helix was found to decrease with a corresponding increase in random coil structures. For xanthan and guar gum solutions, the loss of viscosity as well as shear thinning behavior upon autoclaving were more pronounced at lower concentrations. For lower xanthan concentrations (0.025 wt % - 0.05 wt %), the molecular weight was found to decrease upon sterilization, this decrease being more pronounced for longer sterilization times. For a higher xanthan concentration (0.1 wt %), there was insignificant reduction in molecular weight upon autoclaving, even though a significant decrease in viscosity was observed because of disentanglements. Similar behavior of viscosity change was observed for guar gum solutions. The addition of salt before autoclaving was found to have some stabilizing effect on viscosity of xanthan and HEC solutions. For xanthan solutions, salt addition after autoclaving resulted in recovery of much of the loss in viscosity for small autoclaving times (15 min), especially for lower polymer concentrations. However, for longer autoclaving times (1 hr), the loss of viscosity was more or less irreversible. Salt addition before or after autoclaving did not have significant effect on viscosity of guar gum solutions. Experimental measurements of storage and loss moduli for xanthan and Carbopol solutions supported the viscosity data.

Status: Active.

3. **Title:** **Effect of pH on Interfacial Behavior of α-Lactalbumin at Air-Water Interface**

P.I.: G. Narsimhan
Researcher: Michel Cornec, Research Associate
Sponsor: Available for sponsorship

Objectives: (1) Investigation of the effect of pH on the secondary and tertiary conformations of α-lactalbumin. (2) Investigation of the effect of pH on the surface equation of state of α-lactalbumin at air-water interface. (3) Investigation of the effect of pH on the interfacial rheological properties of α-lactalbumin at air-water interface.

Progress: Molten globule (A) state is characterized by a compact globular configuration having native-like and unfolded tertiary structure, a higher surface hydrophobicity, and greater flexibility. It was hypothesized that upon adsorption, a globular protein adopts the molten globule state configuration. Also, it is likely that interfacial conformational rearrangement would occur more rapidly when the protein adsorbs from the molten globule state. To test this hypothesis, dynamics of adsorption of α-lactalbumin in the native (pH 7) and in the acidic molten globule state (pH 2) were compared. Secondary and tertiary structures were inferred from circular dichroism measurement in the far and near UV. At pH 2 (A state), surface hydrophobicity of α-lactalbumin was found to be 15 times higher than that at pH 7 (native state). Net charge of α-lactalbumin is higher at pH 2 (+18) than that at pH 7 (-2). As a result, an adsorbing protein molecule would experience a stronger repulsive electrostatic energy barrier. Surprisingly, the rate of changes in surface pressure (π) and surface concentration (Γ) as well as their steady state values were found to be higher at pH 2 than that at pH 7, the more flexible protein in the molten globule state being able to overcome the high electrostatic energy barrier. Increase in ionic strength resulted in a decrease in the thickness of the electrostatic double layer, and consequently, the rate as well as the extent of adsorption were found to be larger. However, this effect was observed to be more pronounced at pH 2 than that at pH 7. Also, the diffusion-controlled adsorption phase lasted much longer when the protein was in the molten globule state. Strength developed by the interfacial layer of α-lactalbumin adsorbed from the native and A state configuration were compared by measuring the evolution of the interfacial shear elastic modulus (G') and surface viscosity (η) as a function of time. At all ionic strengths studied, G' and η were found to be higher for native protein. Therefore, it was concluded that a protein in the molten globule conformation is more surface active than its native counterpart. However, interfacial rheological data seem to indicate that the conformation adopted by a protein molecule upon adsorption is different from the molten globule state.

Status: Open.

4. **Title:** **Effect of Gamma-irradiation on Interfacial Properties of Model Proteins**

P.I.: G. Narsimhan
Researcher: Dennis Kim, M.S. Student
Sponsor: Available for sponsorship

Objective: To investigate the effect of gamma-irradiation on the conformation and interfacial properties of four model proteins, namely, α-lactalbumin (ALA), β-lactoglobulin (BLG), ovalbumin (OVA), and lysozyme (LYS) in aqueous solution.

Progress: Irradiation of food is very effective at eliminating pathogens and spoilage microorganisms while maintaining sensory quality. For this reason, the use of gamma-irradiation is likely to increase as a substitute for heat pasteurization of processed foods. However, fundamental knowledge is needed to determine how the functional properties of individual constituents, such as proteins, are affected by irradiation. ALA, BLG, OVA, and LYS were irradiated with doses of 1-10 kGy from a Co-60 gamma-irradiator. The secondary conformation of these proteins was determined by circular dichroism using a Jasco 600 polarimeter. Treatment was shown to induce major changes in the secondary structure of the proteins in solution. For ALA, BLG, and OVA, the content of α-helix was reduced by up to 50% with a corresponding increase in unorganized structures. Continuing study in determining any affects on surface hydrophobicity, elastic modulus, and surface viscosity of these proteins is in progress. This study should provide insights for understanding how gamma-irradiation will affect the functional properties of primary ingredients in food dispersions, such as emulsions, foams, and gels.

Status: Active.

5. **Title:** **Molecular Dynamics in Frozen Systems**
P.I.: P. Cornillon
Researcher: Jinfa Ying, Ph.D. student
Sponsor: Available for sponsorship

Objectives: (1) To measure molecular interactions in frozen systems, like ice cream, using NMR spectroscopy. (2) To characterize the so-called glassy and rubbery states.

Progress: Upon freezing, foods undergo phase transitions that are characteristic of the components and their composition. Those transitions are associated with large variations in the intrinsic properties of foods, viz., viscosity, heat capacity, and thermal conductivity. The stability of foods is dependent on the temperature in which the food product is stored and, hence, on the physical state of the frozen system (glassy, rubbery, etc.). Understanding the molecular dynamics in each state allows a better definition of the concept of water mobility. NMR spectroscopy is a powerful tool for performing such an investigation and is being used in conjunction with DSC, DETA and DMTA analysis.

Status: Active.

6. **Title:** **Water States in Wheat Flour Doughs**
P.I.: P. Cornillon
Researcher: Yong-Ro Kim, Ph.D. student
Sponsor: Available for sponsorship

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

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 occur which are strongly related to water mobility. 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: Active. A manuscript is in preparation.

7. **Title:** **Storage Stability of Frozen Foods and Associated Freezing Damage**
P.I.: P. Cornillon
Sponsor: Available for sponsorship

Objectives: (1) To determine structural and textural damages in foods depending on freezing conditions (time, rate, temperature). (2) To determine the importance of the glass transition temperature on the storage stability of frozen foods.

Progress: Selected food products will be frozen under various conditions to obtain different ice crystal sizes, shapes, and distributions. Various freezing conditions will allow intercellular and extracellular freezing which will produce cell damage, loss of texture, etc. The measurement of those quality losses will be done by various NMR techniques; specifically, relaxometry, diffusion, and imaging. These NMR investigations should provide the most sensitive parameters to freezing damage. To use reliably those NMR results, it is necessary to compare them to classical techniques. Instron analysis is then expected to give references of texture and structure to the NMR parameters. The shelf life of frozen foods is increased as compared to foods stored at room temperature because many chemical reactions are dramatically slowed down, growth of microorganisms is greatly decreased, and in general, the availability of water molecules is reduced. It is recommended to store frozen foods at -18ºC; however, depending on the nature of foods, this industry standard temperature may be increased, e.g., for some fruits and vegetables, introducing lower energy consumption, less quality losses, etc. To challenge the relevance of this standard temperature, the states of water at low temperature need to be understood to determine any linkages between stability and mobility of water and between optimum storage condition and glass transition temperature.

Status: Activation in 2000.

8. **Title:** **Fat Bloom Occurrence and Fat Migration in Chocolate**
P.I.: P. Cornillon
Researcher: Peggy Walter, Undergraduate Student from ENSBANA, France
Sponsor: WCCR

Objectives: (1) To characterize the parameters of influence for fat bloom. (2) To detect fat bloom by NMR and MRI technology. (3) To measure the migration in chocolate of fat from other products like peanut butter.

Progress: It was found from early NMR and MRI examinations of selected chocolate samples that the data could be used to determine the effect of thermal history on fat bloom and to better understand the mechanism of fat bloom. It was found that fat bloom was related to thermal history. Increasing storage time at 21ºC after placing samples 3 days at a higher temperature (32ºC or 28ºC), also induced fat bloom. DSC experiments confirmed the polymorphic form (VI) of the bloomed sample. For the second part of this study, three different components were added separately to the initial composition of dark chocolate and the occurrence of fat bloom was observed. The triacylglycerol 1,3-dibehenoyl-2-oleoyl-glycerol was found to be a good additive to prevent fat bloom. However, NMR and DSC data collected for sucrose and milk powder as additives to chocolate, well known to be fat bloom inhibitors, did not confirm this action. Indeed, fat bloom occurred, but the aspect and structure of fat bloom were different than with chocolate samples without additives. For the third part of this study, the migration of triacylglycerols in commercial dark chocolate samples was analyzed by NMR, MRI, and DSC. This study determined the influence on triacylglycerol migration and fat bloom occurrence of lauric acid and peanut butter or nougat stored respectively at 50ºC and 28ºC. It has been found that triacylglycerol migration was a multi-phase and multi-direction phenomenon. Lauric acid and peanut butter increased the liquid-to-solid ratio of chocolate, thereby avoiding solid lipid transformation from crystals of form V to form VI. This action effectively prevents simultaneous fat bloom. However, it has been observed that nougat, due to its low amount of liquid lipid did not prevent fat bloom occurrence

Status: Suspended. Two manuscripts are under development.

9. **Title:** **Cryoprotection of Proteins by Highly Branched Oligosaccharides**
P.I.: P. Cornillon
Researcher: Joong-Hyuck Auh, Ph.D. student from Seoul National University
Sponsor: Available for sponsorship

Objectives: (1) To determine the cryoprotection characteristics of a highly branched oligosaccharide. (2) To determine water mobility changes upon freezing.

Progress: Unfrozen water content and NMR relaxation times were measured on BSA solutions with various additives: sucrose, sorbitol/sucrose, and highly branched oligosaccharide. It was shown that there are differences in the way the additives protect proteins by decreasing water mobility and formation of ice. The highly branched oligosaccharide was shown to have better cryoprotection abilities than sucrose or the mixture of sorbitol and sucrose.

Status: Suspended. A manuscript is under preparation.

10. **Title:** **MDSC Study of the Gelatinization of Starch Mixtures**
P.I.: P. Cornillon
Researcher: Antje Gonera, Undergraduate student from University of Dresden
Sponsor: Available for sponsorship

Objectives: (1) To separate the glass transition event from the gelatinization peak. (2) To analyze the thermal events associated with glass transition.

Progress: Various starch mixtures with sugars and gums were prepared and analyzed by modulated DSC so that the reversing and non-reversing heat flows could be obtained. In general, it was shown that the midpoint of the glass transition event was almost simultaneous to the gelatinization peak temperature. Glass transition was often associated with devitrification and enthalpic relaxation. After melting and storage, the glass transition event did not have the same characteristics as that of fresh solutions.

Status: Active. A manuscript is under preparation.

11. **Title:** **Effect of Microwaves on Thawing of Frozen Foods**
P.I.: P. Cornillon
Sponsor: Available for sponsorship

Objectives: (1) To determine the effect of microwaves on the structural and textural properties of frozen foods. (2) To relate these properties to water mobility.

Progress: Frozen foods will be thawed by microwaving, and the effect of power intake and time will be evaluated. Textural, rheological, and thermophysical properties of thawed foods will be determined along with the NMR relaxation times and diffusion coefficient. A correlation between these parameters will be studied to determine the effect of processing.

Status: Under development. Seeking development partner.

12. **Title:** **Reagent Access to Starch Granules**
P.I. J.N. BeMiller
Researcher: J. Gray, M.S. Student

Objective: Determine the relationship of reagent size to penetration into starch granules.

Progress: This subproject is part of a larger project the goal of which is to determine means of developing improved starch products within the restrictions of existing limits of use and/or add-on of allowable reagents. Stated in another way, the goal is to provide information that can be used to develop new value-added starch products through process control.

Microscopic techniques were used to determine accessible regions in various starches under swelling conditions. Fatty acyl chlorides of increasing chain length (C_6-C_{16}) were reacted with 2-aminopyridine to produce the corresponding fatty acyl amides. Starch granules (common corn, waxy maize, potato) were treated with the series of fluorescent amides under a variety of conditions: anhydrous (hot pyridine), aqueous (no heat), and aqueous alkali (49°C with and without swelling-inhibiting salts). Granules were isolated, then viewed by confocal laser scanning microscopy (CLSM) to obtain information about the relationship between reagent penetration and the degree of granule swelling. Confirmed by this investigation is the heterogeneity of starch granules from any source and that the molecules in the area surrounding the hilum are less densely packed. Hot-pyridine-swollen common corn starch granules showed no substantial trends in penetration as the chain length of the fluorescent fatty acyl amides (C_6-C_{16}) increased. Common corn and potato starch granules swollen in room temperature water showed cutoffs for granular exclusion at C_{14} and C_{12}, respectively. Common corn, waxy maize, and potato starch granules treated under industrial etherification conditions (heat, pH $\approx$ 11, swelling-inhibiting salts) were less accessible to the C_6, C_8, and C_{10} fluorescent amides when sodium citrate was present than when sodium sulfate was used and less accessible in either case than in water alone or hot anhydrous pyridine. However, appreciable differences between inhibition by sodium sulfate and sodium citrate were not observed in every case.

Status: Completed. Manuscript in preparation.

13. **Title:** **Architecture of Corn Starch Granules**
P.I. J.N. BeMiller
Researcher: V.K. Villwock, Ph.D. Student
Ninik Gunawan, M.S. Student
Sponsor: USDA

Objectives: (1) Location of the channels leading to the interior of corn and sorghum starch granules. (2) Determination of the origin of channels and a central cavity during development of corn starch granules. (3) Determination of genetic control, if any, of channelization.

Progress: The radial, tube-like channels of corn and sorghum starch granules which penetrate from the external surface inward toward a cavity at the hilum were found to vary in depth of penetration from granule to granule. Most, but not all, channels spanned the entire granule matrix, from the outer surface to the central cavity. Under slight swelling conditions (water), cavities may have swelled somewhat closed, while channels remained open. Swelling also affected the permeability of the granule matrix to dye molecules. Penetration of an aqueous dye solution occurred primarily from the central cavity outward and laterally from channels. Under the slight swelling conditions, colloidal gold particles filled channels and cavities, showing that they are voids (paper B.1).

Granular structures were observed using confocal microscopy and an array of fluorescent and reflective probes of various sizes. Results showed that molecules with molecular weights far in excess of the commonly accepted exclusion limit for starch (1000 da) were capable of penetrating the granule matrix. Use of fluorescent microspheres demonstrated that channels in corn starch exist under pristine native conditions at all developmental stages and, thus, are not artifacts produced from drying or solvent treatment (Thesis E.4).

Status: Active. One manuscript in preparation (B.1).

14. **Title:** **Reaction Sites of Corn Starch Granules**
P.I. J.N. BeMiller
Researcher: J. Gray, Ph.D. student
Sponsor: 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. In order to determine the effects, if any, of process variables on the sites of granule modification, there must be a method to determine where reaction occurs. This project addresses this first step in such an investigation. The results should expand our understanding of the natures of starch granules and has 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. One study has been completed; one paper has been published and one manuscript is in preparation. One method (back-scattered electron imaging) for observing granular reaction patterns of modified starch has been developed.

Being investigated now is whether a fluorescent dye that binds specifically to the added functional group and confocal scanning laser microscopy can also be used to detect where derivatization has taken place. A second part of the project is to determine (using either the previously established method or a new one) any effects of pH, temperature, kind of salt, and salt concentration on the homogeneity/heterogeneity of granule modification.

Status: Active.

15. **Title:** **Edible Films**
P.I. J.N. BeMiller
Researcher: X. Shi, Ph.D., Research Associate
Sponsor: Available for sponsorship

Objective: Preparation of self-supporting films (films with proper dry strength and films with proper wet strength) from edible ingredients.

Progress: Various self-supporting edible and biodegradable packaging films were made from polysaccharides. Different strategies and technologies were used for different types of polysaccharides and different application targets. Synergistic effects in mechanical properties were found for solution cast agar-konjac glucomannan-starch blend films. Blending ratio and preparation process were optimized. These ternary blend films were water sensitive. Heating films in an alkaline condition improved their wet strength. To improve the chewability of regenerated cellulose films, cellulose was slightly methylated before regeneration. To better control the wet strength of chitosan films, which otherwise would be too tough for edible film application after storage due to polymorph transformations from hydrated crystallites to anhydrous crystallites, a polymer blend with CMC was used. Polymorph transformations in the blend film were decreased. The mechanisms for property improvement were investigated at the molecular level by x-ray and dynamic mechanical thermal analysis (DMTA). Partial miscibility was revealed by the dependence of glass transition temperature on composition of agar-starch blends. Moderate phase separation was found to be desirable for achieving high elongation for agar-konjac glucomannan-starch ternary blend films.

Status: Inactive. Manuscript being prepared.

16. **Title:** **Identification of Starch from Different Botanical Sources, from Various Maize Endosperm Mutants, and after Various Modifications from Ghost Microstructures**
P.I.: J.N. BeMiller
Researcher: P. Purdue, Technician
Collaborator: Prof. D.V. Glover
Sponsor: Available for sponsorship

Objectives: (1) Application of our method, which predicts the cooking and rheological behaviors of starches, to evaluate maize genotypes from various genetic combinations of endosperm mutants for unique, promising starches. (2) Use of the method to understand the effect of chemical modifications on starch granule behavior using commercial products with desirable characteristics. (3) Use of the method to characterize the effect of endosperm mutant alleles at a single gene level on maize starch behavior. Use of two contrasting genetic backgrounds representing the two major heterotic groups of maize and two environments to assess their effect on starch ghost microstructure. (4) Evaluation of various combinations of genes available at Purdue with a goal of mimicking the effects of chemical modifications and examining the effects of gene interactions on starch granule microstructure. (5) Use of the method as a screening tool to identify desirable mutant combinations which produce unique and potentially useful starches.

Progress: Starches from maize endosperm mutants are being screened by comparison with a library of chemically modified starches. The method employed is simple, reliable, practical, and powerful as a screening tool to select starches based on a prediction of their functional properties. Inbred lines, double mutants, including two dosage studies, triple mutants, and synthetic populations in two different backgrounds (Oh43 and B73) are being examined and categorized.

Unthinned, derivatized starches were prepared with degrees of substitution within the ranges allowed commercially. A 4 × 4 matrix was constructed for both common corn and waxy maize starches. Four levels of stabilization (hydroxypropylation) were applied: zero, low (DS 0.02), medium (DS 0.1), high (DS 0.2). Four levels of crosslinking (phosphorylation with phosphoryl chloride) were also applied: zero, low (0.01%), medium (0.05%), high (0.1%). 22 (of the 30 possible) modified starches were prepared using combinations of the derivatization reactions in order to produce a library of unthinned, modified starches. Each has been examined by the screening method for comparison purposes.

The starches examined to date provide a continuous spectrum of cooking behaviors. Patterns are clearly evident, but sharp differences between each category in the spectrum do not exist. Further analysis will establish relationships between genotype and granule behavior.

Status: Suspended/Inactive

17. **Title:** **Investigation of Starch Ghosts/Envelopes**
P.I.: J.N. BeMiller
Researcher: R. Kavitha, Ph.D., Research Associate
Sponsor: Available for sponsorship

Objective: Determination of why some starches, upon cooking, yield almost intact ghost structures and some only a few, very small fragments (as determined in project 16). If it can be determined what holds the outer shell structure together, the next objective will be to determine if it can be enhanced by breeding to produce a native starch that behaves like a crosslinked starch.

Progress: Granule ghosts have been isolated. Exhaustive digestion with amylases has yielded very small amounts of products which may be the site of crosslinkages. The same products can be obtained from complete acid-catalyzed hydrolysis. An original mixture has now been purified to two acid- and enzyme-resistant substances, at least one of which appears to be disaccharide size. Neither of their chemical structures nor, therefore, the nature of the crosslinks has been determined.

Status: Active.

18. **Title**: **Analysis of Modified Starches**
P.I.: J.N. BeMiller
Researchers: X. Shi, Ph.D., Research Associate

Objective: Characterization of the derivatized amylose and amylopectin components of chemically alkylated starches.

Progress: Common corn starches were modified in 0.56 M sodium sulfate solution and in 0.31 M potassium citrate solution. It was found that about 1.8 times of reagent (propylene oxide) was needed to get a same molar substitution (MS) when potassium citrate was used. Three modified starches were fractionated on a size-exclusion column to separate amylose from amylopectin. The MS of common corn starch modified in sodium sulfate solution (I) was determined to be 0.096, of amylose 0.109, and of amylopectin 0.090. The MS of another preparation of the common corn starch modified to a greater extent in sodium sulfate solution (III) was determined to be 0.186, with the MS of the amylose being 0.225 and of the amylopectin 0.171. The MS of common corn starch modified in potassium citrate solution (II) was determined to be 0.099, with the MS of the amylose being 0.121 and of the amylopectin 0.096. In all three cases, amylose was derivatized to a greater extent than was amylopectin. By comparing preparations I and III, it was determined that the greater the derivatization, the greater the preference for derivatization of amylose. By comparing preparations I and II, it was determined that the preference for amylose derivatization was greater for common corn starch modified in potassium citrate solution than in sodium sulfate solution when the MS values for the two preparations were essentially the same, i.e., about 0.1. No significant difference was found in RVA profiles between starches I and II.

Status: Completed. Manuscript accepted for publication (paper B.9).

19. **Title:** **Starch Modification with Natural Products**
PI: J.N. BeMiller
Researcher: B. Ryan Manis, Ph.D. Student
Sponsor: Available for sponsorship

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

Progress: Motivation for this project was a 1943 patent (A.D. Fuller, U.S. Patent 2,317,752; application 1939), which describes a modified starch product made with various substances, including proteins, in the presence of hypochlorite that behaves like a crosslinked starch. In this project, waxy maize starch is modified by oxidation with hypochlorite in the presence of various proteins. After modification, excess protein is washed from the starch granules. Final starch products are evaluated by rapid viscoanalysis (RVA), and the amount of protein remaining in the starch granules is quantified.

The first goals of this project are to improve the properties of waxy maize starch using the modification techniques outlined in the 1943 patent and to optimize experimental conditions. Reaction time, temperature, amount of oxidant, and type and amount of protein have been varied to obtain the best possible product which is characterized by an increase in peak and breakdown viscosity. So far, it has been found that the RVA behavior of waxy maize starch can be changed toward that of lightly crosslinked product in this way; but the effect is not dramatic and the efficiency is low. Other variables to be investigated include the presence of salts and different starches.

Another goal of this research project is to determine the mechanism of the starch modification, i.e., how the starch and protein are interacting in the presence of hypochlorite to change the properties of the starch. The most likely supposition is that there is a Schiff base reaction between carbonyl groups on the oxidized starch and amino groups on the protein, but diamines of various chain lengths are ineffective. So, the mechanism of the reaction remains to be determined. Structure determination and location of protein within the granule will be conducted.

Status: Active.

20. **Title:** **Determination of Water Sorption by Starch Under Conditions of High pH and Salt Concentration**

PI: J.N. BeMiller
Researcher: V.K. Villwock, Ph.D. Student
Sponsor: Available for sponsorship

Objectives: (1) Determination of water uptake (swelling) of starch granules under normal derivatization conditions. (2) Determination of the effect of various salts in controlling swelling.

Progress: The importance of this work is related to the belief that the efficiency of the derivatization process is related to the degree of swelling. Current methods for measurement of water sorption by starch granules do not work under conditions normally used for hydroxyalkylation, i.e., high pH and a salt to prevent gelatinization. A large number of new approaches have been investigated for determining water sorption of granular starch with the ultimate goal of monitoring water sorbed during chemical derivatization under high salt/pH conditions. Only two showed some promise and were pursued further. Blue dextran exclusion (including alternative polymer-dyes) and NMR relaxometry techniques were investigated. Key problem areas of the blue dextran method were identified as the adsorption of aromatic ring-containing functional groups (dye), which is aggravated by the presence of lyotropic salts, and the insolubility of leached amylose and its incompatibility with dextran and other water-soluble polymers. It was found that heating mixtures was a requirement for significant losses of blue dextran to occur. Using relaxometry, water contents of corn starch could be accurately determined only in the absence of bulk water. In the end, after 4-5 years of experimentation, no solution to the problem has been found.

Status: Active.

21. **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, Procter & Gamble Co.

Objectives: 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. Earlier, a simple way to prepare *C*-glycosides and aza *C*-glycosides was developed. The reaction involves oxidation of D-glucose diethyl dithioacetal (with spontaneous cyclization) to the corresponding (α-D-arabinopyranosyl)-di(ethyl sulfonyl)methane. The current project began as an investigation to determine if the process could be further simplified via use of 1,3-dithiopropyl dithioacetals. In the process, a new reaction was discovered. This reaction gave, for example, from D-glucose a derivative of D-erythrofuranosyl formaldehyde, i.e., *C*-(D-erythrofuranosyl)-CHO. Development and extension of this reaction to produce pharmacologically-active products is underway. Papers A.6, B.3, and B.10 are related.

Status: Active.

22. **Title:** **Relationship of Starch Granule Subpopulations to Reactivity**
P.I.: J.N. BeMiller
Researcher: R. Kavitha, Ph.D., Research Associate
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 preparation is heterogeneous. From this information, it can be hypothesized that there are subpopulations of granules within a preparation from a single botanical source that differ.

There are literature reports of granules of a given preparation being separated by size and various properties of granule fractions being determined. In this project, a preparation of starch will be derivatized. Granules will be separated by size after derivatization and each fraction will be characterized. Initially, as a model, wheat starch will be used, and it will be hydroxypropylated. After separation into large and small granules, MS values of the whole granules, the amylose, and the amylopectin will be determined. Longer term, this procedure will be applied to other starches where possible. If significant differences in subpopulations are found, the ultimate goal will be to determine if and how the ratios of subpopulations can be altered.

Status: Active.

23. **Title:** **Openness of Derivatized Starch Granules**
P.I.: J.N. BeMiller
Researcher: A.M. Duldulao, MS Student
X. Shi, Ph.D., Research Associate
Sponsor: Available for sponsorship

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

Progress: I. The following starches have been hydroxypropylated to MS 0.1 in the presence of (a) sodium sulfate and (b) sodium citrate (which results in a greater restriction of swelling): common corn, waxy maize, potato, tapioca. The 8 hydroxypropylated starch preparations are being subjected to conditions used to make Nägeli dextrins, i.e., conditions that preferentially depolymerize amorphous (more accessible) regions as opposed to more crystalline, less-accessible regions. Initial results show that the starch chain fragments released (solubilized) first had considerably greater MS values (approximately double) than did the overall starch, indicating that the more substituted areas are more susceptible to hydrolysis. More importantly, it confirms the heterogeneous nature of granules, or a population of granules, since it cannot be ruled out that the results are produced by hydrolysis of a subpopulation of highly substituted granules rather than by hydrolysis of more open, more swollen areas of each granule. The data also show that hydroxypropylated starches undergo depolymerization from 2-4 times more rapidly than do unmodified starches, that there are only slight differences between hydrolysis of starches modified in the presence of sodium sulfate or sodium citrate to the same MS level, and that there are definite differences between the susceptibility of unmodified and modified common corn, waxy maize, potato, and tapioca starch granules.

II. After experimentation, the same modified starches in aqueous slurry were subjected to time and temperature conditions that leached hydroxypropylated amylose from granules. Each leachate is being examined for amylose and amylopectin content (by SEC chromatography) and for MS.

Status: Active.

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

P.I.: J.N. BeMiller
Researcher: X. Shi, Ph.D., Research Associate
Sponsor: Available for sponsorship

Objective: Examination of the effect of various gums in solution on the gelatinization and pasting temperatures of waxy maize starch 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 is being used for viscosity measurement while employing a Brabender ViscoAmylograph and its programs for heating. Early results show some apparently synergistic interactions with specific pairs of a starch and a gum.

Status: Active.

25. **Title:** **Branched Polysaccharides in the Gellan Family**
P.I.: R. Chandrasekaran
Researcher: W. Bian, Ph.D. Student
Sponsor: Available for sponsorship

Objective: Determination of morphology of S-657 and rhamsan.

Progress: Both S-657 and rhamsan have the same backbone as does gellan, but have different disaccharide side chain on, and linkages to, every tetrasaccharide repeat in the main chain. Preliminary x-ray data on oriented fibers with limited crystallinity indicate that both polymers adopt double-helical structures similar to that of gellan. Experiments over a range of pH and ionic conditions are being conducted in order to improve specimen crystallinity so that detailed structure analysis is possible.

Status: Active.

26. **Title:** **Molecular Details of the Junction Zones in Alginate and Pectin Gels**
P.I.: R. Chandrasekaran
Researcher: Y. Sun, Ph.D. Student
Sponsor: Available for sponsorship

Objective: Determination of structural details of the junction zones.

Progress: X-ray fiber diffraction experiments are under way to trap calcium alginate and calcium pectate gels in polycrystalline and oriented fibers in order to determine the morphological features of their junction zones.

Status: Active.

27. **Title:** **Influence of Ions on Carrageenan Structures**
P.I.: R. Chandrasekaran
Researcher: Srinivas Janaswamy, Ph.D., Research Associate
Sponsor: Available for sponsorship

Objective: Structural details of interactions of cations with carrageenan.

Progress: In order to determine the structural role of cations on the gelation properties of carrageenans, we have initiated a systematic x-ray fiber diffraction analysis on these polymers in the presence of mono- and divalent cations. Preliminary data suggest that the sodium salt of kappa-carrageenan has an ordered helical structure. Experiments are in various stages with regard to other cations.

Status: Active.

28. **Title:** **Molecular Structures and Interactions of Cellulose and Related Polysaccharides**
P.I.: R.P. Millane
Sponsor: NSF

Objective: Determination of the molecular and crystal structures of cellulose and related polysaccharides and their relationship to interactions and properties.

Progress: The crystal structure of native *Valonia* cellulose had been determined previously, and resolved a long-standing question concerning the packing of native celluloses (paper A.14). Current work is aimed at a detailed analysis of the mixed $I\alpha/I\beta$ form of native celluloses. A by-product of this work has been theory and methods for the analysis of diffraction by "triclinic" and "tilted" unit cells (paper A.16).

Status: Active.

29. **Title:** **Modeling and Analysis of Disordered Crystalline Polymers**
P.I.: R.P. Millane
Researcher: J.L. Eads, Ph.D. Student
Sponsor: NSF

Objective: Develop methods for modeling and analyzing diffraction from disordered crystalline polymers.

Progress: Crystalline polymer systems often exhibit disorder in the way that the molecules pack together. Studies of two commonly used models of disorder, the paracrystal and the perturbed lattice, have shown that they are very similar in some regimes (of disorder and crystallite size) but somewhat different in others. They both give similar diffraction patterns, however (paper C.11). Packing of polymer molecules in a crystalline array is described by a two-dimensional lattice. Models of two-dimensional systems are not as easily constructed as for one-dimensional systems. We have therefore examined the statistical properties of the two-dimensional ideal paracrystal and its diffraction pattern. Of particular interest is the hexagonal lattice, since many polysaccharides pack on such a lattice. We have shown that the ideal paracrystal is not a good model of disorder in such a system since it cannot accommodate equivalent statistics between equivalent nearest neighbors. Future work will involve application of the two-dimensional perturbed lattice model to analyze specific disordered polymer systems.

Status: Active.

30. **Title:** **Methods to Locate Guest Molecules in Crystalline Polymer Systems**
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. These interactions often involve bound counterions and water molecules. In order to characterize these interactions, crystal structures of these polysaccharides need to be solved, not only for the polymer, but also for the guest molecules. Currently, guest molecules are located using methods from single crystal crystallography. We have developed methods to locate guest molecules that take into account the nature of the data available from crystalline polymer fibers (papers A.15 and A.18). Simulations show that these methods should be more reliable than existing methods. Currently, we are extending this method to accommodate crystals with symmetry, and applying it to data from specific polymer systems.

Status: Active.

31. **Title:** **Simulation of Gel Networks and Viscoelastic Properties**
P.I.: R.P. Millane
Researcher: A. Goyal, Ph.D. Student
Sponsor: Open for sponsorship.

Objective: Use network models to help understand relationships between chemical structure and viscoelastic properties of polysaccharide gels

Progress: Approach is to use statistical mechanical simulations of polysaccharide network formation to examine network properties, and thence viscoelastic properties, as a function of the polysaccharide primary structure parameters such as frequency and length of interacting segments.

Status: Active.

32. **Title:** **New Algorithms for Protein Crystallography**
P.I.: R.P. Millane
Researcher: J.L. van der Plas, Ph.D., Research Associate
Sponsor: NSF

Objectives: Develop algorithms to help determine protein crystal structures with less experimental data than is currently possible.

Progress: Current methods for determining protein structures using x-ray crystallography usually depend on collecting x-ray data from native and heavy-atom-derivative crystals. Preparation of the latter crystals is often time-consuming and expensive, and is not always possible. New methods for processing data from native crystals only, and utilizing symmetry and solvent region information, to determine structures are being developed (paper A.18). Simulations of application to spherical viruses show the power of the new approach. The methods are currently being extended to higher resolution and to proteins with lower symmetry.

Status: Active.

33. **Title:** **Development of a Rapid Screening Assay for a High Protein Digestibility Trait in Sorghum**
P.I.: B.R. Hamaker
Researchers: A. Aboubacar, Ph.D., Research Associate
Sponsors: Texas Grain Sorghum Board

Objectives: (1) To develop a screening assay for breeders to differentiate normal from highly digestible sorghum cultivars.

Progress: These studies have originated out of a need to improve the relatively poor protein digestibility of sorghum grain reported in both humans and livestock. Previous studies in our laboratory showed that sorghum protein bodies are enzyme-resistant compared to protein bodies of other cereals, and contain a protein at the protein body periphery that is difficult to digest. About six years ago, we discovered a mutant that had substantially higher protein digestibility for both raw and cooked flour. This highly digestible sorghum grain had remarkably different protein bodies with folded structure, rather than spherical, and a translocation of the enzyme-resistant protein to the interior of the body. A rapid screening assay was developed to identify the highly digestible mutant in breeding lines for incorporation of this trait into elite cultivars. Last year, we reported on an electrophoresis-based assay that accurately discriminated between highly digestible and normal sorghum lines. In this last year of the project, a simple microtiter plate turbidity-based assay was devised to rapidly and inexpensively screen sorghum breeding lines. The assay has an output of approximately 200 samples per day per operator. This project ended December 1999 with completion of development of the two assays (electrophoresis- and turbidity-based) to identify highly digestible lines.

Status: Completed.

34. **Title:** **Three-component Interaction Among Starch, Protein, and Free Fatty**

Acids Affecting Paste Viscosity

P.I.: B.R. Hamaker

Researcher: G. Zhang, Ph.D. student

Sponsor: Available for sponsorship

Objective: To investigate the manipulation of paste viscosity using a model three-component system and the mechanism involved.

Progress: Recently, we identified a three-component interaction among amylose, free fatty acid, and soluble protein that resulted in a 2-3 fold increase in RVA cooling-stage paste viscosity. The novel aspect of this discovery was that all 3 components are required for the change in functionality to occur. Using a model system containing whey protein, a variety of free fatty acids, and sorghum or corn starch, the mechanism of the interaction was investigated. DSC thermal profiles revealed that the enthalpy of the amylose-free fatty acid complex was significantly reduced when whey protein was added to the system, thereby suggesting that the protein competes with amylose for binding of the free fatty acid. X-ray diffraction patterns showed that the presence of the protein produced sharper V-type patterns, suggesting a more ordered, crystalline structure. Further work showed that the protein was solubilized by the amylose-free fatty acid complexes. HPSEC separation of the soluble material indicated that a high MW complex (about 1 million da) was formed among the 3 components. The complex appears to be stabilized by intermolecular disulfide bonds and electrostatic forces. Paste viscosity may be altered due to formation of this large complex formed by interaction between the lipid-protein and lipid-amylose complexes.

Status: Suspended.

35. **Title:** **Influence of Kernel Constituents on Texture of Corn- and Sorghum-based Products**

P.I.: B.R. Hamaker

Researchers: N. Mix, M.S. Student
A. Tandjung, M.S. Student
B. Bugusu, M.S. Student
X. Han, Ph.D. Student

Sponsors: Kellogg Company (B.B., A.T.), U.S. Agency for International Development (N.M), Open (X.H.)

Objective: (1) To determine the role of corn α-zein and α-kafirin proteins in texturization of extruded cereal products and sorghum-wheat composite bread. (2) To investigate the origin and further characterize a previously identified low-molecular-weight, branched starch component that highly correlated to cooked sorghum couscous texture. (3) To investigate starch granular and fine structural characteristics that determine pasting and gelling properties.

Progress: (Obj. 1) Our previous work showed that zein, the storage protein of corn comprising about 70% of endosperm proteins, is released from the rigid confines of protein bodies and dispersed at SME's beginning at about 100 kJ/kg (papers A.12, A.13). In this year's work, corn gluten meal, mixed in a model system containing corn starch with or without added unrefined corn oil, was extruded under two different conditions.

Examination of physical properties of the extrudate showed differences due to presence of the protein. In another study, the ability of prolamin proteins (zein or kafirin) to form viscoelastic fibrils in a bread system were examined. Commercial zein added to a 20% sorghum-wheat composite flour resulted in marked improvement in dough strength and extensibility, and in bread loaf volume. This occurred only when zein was incubated and mixed at 35^{o}C, a temperature above the glass transition temperature of zein. Confocal laser scanning microscopy of the dough and bread, using antiserum against α-zein to visualize the zein protein, showed that zein formed fibrils exterior to the wheat gluten fibrils that supported the dough structure. Further work will show whether kafirins in sorghum flour can be made to contribute to dough and bread structure.

Status: Active.

Progress: (Obj. 2) In past work on starch fractions related to sorghum couscous texture, we found a soluble, low-molecular-weight (appearing on a SEC profile at MW below the amylose peak) branched starch component that highly correlated (r=0.89) with cooked couscous stickiness. In the past year, we conclusively showed that the low-MW fraction originates from damaged starch during milling. More severe ball-milling produced more of the product that, in turn, caused greater stickiness of starch gels. Our current work on this project investigates the generation of fragmented starch polymers from a variety of milling techniques and their affect on gel functional properties.

Status: Active.

Progress: (Obj. 3) Ten rice varieties were obtained with similar amylose contents, but that substantially differed in starch RVA pasting profiles. Amylopectin fine structural analysis showed fairly high and significant correlation between the proportion of long and short linear chains and breakdown viscosity. This suggests that fine structure impacts granule structure to the degree that susceptibility to shear breakdown of swollen granules is affected. Other studies have focused on the potential role of granule bound starch synthase (GBSS) on the functional properties of starch. Using multiple regression analysis, a relationship was drawn relating to amount of GBSS and peak viscosity. It was noted that some GBSS leaches out of granules during the starch isolation procedure, and that this was varietal dependent. Knowledge of the factors that determine the rigidity of the gelatinized swollen starch granule will help in designing and identifying starches that are naturally resistant to shear breakdown.

Status: Active.

36. **Title:** **Effects of Lime Cooking on Corn Starch and Proteins**
P.I.: B.R. Hamaker
Researcher: M.B. Miklus, Ph.D. Student
Sponsor: Frito-Lay

Objective: To investigate the role of corn starch and proteins in the formation of the cohesive, doughy structure of corn masa.

Progress: Studies on masa were continued in the past year and the project was completed in the Fall. A soluble fragmented starch fraction was identified in masa that highly correlates to masa stickiness. Our studies show that the origin of this component is most likely at the masa mill, where the amylopectin molecule apparently is sheared at the level of the long B chains that span clusters within the molecule. Other work in this project revealed that corn zein proteins form high-MW complexes when lime and heat are present in the system. It is unknown, however, if and how these complexes may affect product texture.

Status: Completed.

37. **Title:** **Characterization of the Extrudate Expansion Phenomenon and its Effect on the Mechanical Properties of Extrudates**
P.I.: O. H. Campanella
Researcher: Kelly Anne Ross
Sponsor: Available for sponsorship

Objectives: (1) To determine the effects of extruder input variables on the rheology of the food melt and consequently the expansion behavior of the food melt. (2) To examine how the effects of these variables are manifested in the final extruded product in terms of its mechanical properties and cellular structure.

Progress: The study of the expansion phenomenon of extrudates relies on knowledge of the rheological properties of food melts, since melt viscosity is an important parameter in determining the expansion of extrudates. Processing conditions and raw material composition will affect the rheology of the food melt, thereby affecting the structure of the final product. Factors, namely, nucleation, water diffusion, heat transfer, and glass transition need to be considered to completely understand the extrudate expansion phenomenon. Measurement of the rheological properties of the food melt and quantification of the mechanical and cellular properties of extrudates will be used as tools to achieve a relationship between input variables and final product quality.

Status: Active. A review paper (paper B.16) is in press.

38. **Title:** **Identification of Causes for the Stickiness of Dough**
P.I.: O. H. Campanella
Researcher: Stephen Christanto, M. S. student
Sponsor: Available for sponsorship

Objective: Dough stickiness is a major problem in bread industries, and what actually causes the stickiness on dough has not yet been identified.

Progress: (1) A rheological method for measurement of stickiness has been fine-tuned to a specific application. (2) The use of milling for different types of wheat under different conditions to find a correlation between milling conditions and stickiness of dough made from milled flour is in progress. (3) Use of an analytical method on flour milled under different conditions to determine the condition of the starch and whether starch damage is one of the causes for stickiness is also underway.

Status: Active.

PUBLICATIONS AND OTHER SCHOLARLY ACTIVITIES

A. Papers, Books, and Book Chapters Published

1. **M. Cornec**, **D. Cho,** and **G. Narsimhan**, Adsorption dynamics of alpha lactalbumin and beta lactoglobulin at air-water interfaces, *J. Colloid. Int. Sci*., 214 (1999) 129-142.

2. **M. Cornec**, **D.A. Kim**, and **G. Narsimhan**, The dynamic adsorption of alpha-lactalbumin in native and molten globule conformation, *Proc. 6th Conf. Food Eng. (CoFE 99)*, G.V. Barbosa Canovas and S.P. Lombardo, eds., 621-626.

3. **R. Chandrasekaran**, X-ray and molecular modeling studies on the structure-function correlations of polysaccharides, *in* Application of Polymers in Foods, H.N. Cheng, G. Cote, and I.C. Baianu, eds., Wiley-Vch, Weinheim, Germany; *Macromol. Symp.*, 140 (1999) 17-29.

4. **James N. BeMiller**, Structure-property correlations of non-starch food polysaccharides, *in* Application of Polymers in Foods, H.N. Cheng, G. Cote, and I.C. Baianu, eds., Wiley-Vch, Weinheim, Germany; *Macromol. Symp*., 140 (1999) 1-15.

5. **V. Kurtis Villwock,** Ann-Charlotte Eliasson, José Silverio, and **James N. BeMiller**, Starch-lipid interactions in common, waxy, *ae du*, and *ae su2* maize starches examined by differential scanning calorimetry, *Cereal Chem*., 76 (1999) 292-298.

6. **Duy-Phong Pham-Huu**, Mária Petrušová, **James N. BeMiller**, and Ladislav Petruš, The first synthesis of a nitromethylene-linked C-(1$\rightarrow$2)-disaccharide, *Tet. Lett*., 40 (1999) 3053-3056.

7. **J.N. BeMiller**, (Book Review) Carbohydrate Mimics. Concepts and Methods, Y. Capleur, ed., John Wiley & Sons, New York, 1998, *Pharm. Res.*, 16 (1999) 779.

8. **J.N. BeMiller** and 15 others (Committee on Biobased Industrial Products, National Research Council), Biobased Industrial Products: Priorities for Research and Commercialization, National Academy Press, Washington, DC, 1999.

9. A. Rahmanifar and **B.R. Hamaker**, Potential nutritional contribution of Quality Protein Maize in poor communities: a close-up on children's diets, *Ecol. Food Nutr.,* 38 (1999) 165-182.

10. **A. Aboubacar** and **B.R. Hamaker**, Physicochemical properties of flours that relate to sorghum couscous quality, *Cereal Chem.*, 76 (1999) 308-313.

11. **G. Zhang** and **B.R. Hamaker**, SDS-sulfite increases enzymatic hydrolysis of native sorghum starches, *Starch/Staerke*, 51 (1999) 21-25.

12. **S.J. Batterman-Azcona**, J. Lawton, and **B.R. Hamaker**, Effect of specific mechanical energy on protein bodies and α-zeins in corn flour extrudates, *Cereal Chem.*, 76 (1999) 316-320.

13. **S.J. Batterman-Azcona**, J.W. Lawton, and **B.R. Hamaker**, Microstructural changes in zein proteins during extrusion, *Scanning*, 21 (1999) 212-216.

14. **R.P. Millane**, The ups and downs of native cellulose structure, *Fiber Diff. Rev.,* 7 (1998) 36-40.

15. **S. Baskaran** and **R.P. Millane**, Model bias in Bayesian image reconstruction from x-ray fiber diffraction data, *J. Opt. Soc. Am. A*., 16 (1999) 236-245.

16. **V.L. Finkenstadt** and **R.P. Millane,** CPRL: A program to plot the cylindrically projected reciprocal lattice for fiber diffraction patterns, *J. Appl. Crystallogr*., 32 (1999) 551-553.

17. **R.P. Millane** and M.A. Fiddy, eds., Feature issue on "Signal Recovery and Synthesis," *J. Opt. Soc. Am. A*, 16 (1999) 1741-1872.

18. **R.P. Millane**, **J. van der Plas**, and **S. Baskaran,** Image reconstruction in x-ray crystallography: some new developments, *Proc. Image Vision Computing New Zealand 1999*, D. Pairman and H. North, eds, Landcare Research, Lincoln, New Zealand, 67-72.

19. M.A. Baker, **O.H. Campanella,** and M.R. Okos, Rheological properties of various wheat flour doughs under small and large deformations and their relationship to final product quality, *Proc. 6th Conf. Food Eng.* (CoFE' 99), G.V. Barbosa-Canovas and S.P. Lombardo, eds., 211-216.

20. H. Zheng, M.P. Morgenstern, **O.H. Campanella,** and N.G. Larsen, Effect of mixing on the rheological properties of dough, *Proc. 6th Conf. Food Eng*. (CoFE' 99), G.V. Barbosa-Canovas and S.P. Lombardo, eds., 224-230

21. M. Sterling, M.R. Okos, and **O.H. Campanella,** Determination of transition temperature of semolina using plate-plate viscometer, *Proc. 6th Conf. Food Eng*. (CoFE' 99), G.V. Barbosa-Canovas and S.P. Lombardo, eds., 398-402.

22. B.F. Willis, M.R. Okos, and **O.H. Campanella,** Effects of glass transition on stress development during drying of a shrinking food system, *Proc. 6th Conf. Food Eng.* (CoFE' 99), G.V. Barbosa-Canovas and S.P. Lombardo, eds., 496-501.

23. M.P. Morgenstern, H. Zheng, M. Ross, and **O. H**. **Campanella**, Rheological properties of sheeted wheat flour dough measured with large deformations, *Int. J. Food Prop.*, 2 (1999) 265-276.

B. Papers and Book Chapters in Press

1. **Kerry C. Huber** and **James N. BeMiller**, Channels of maize and sorghum starch granules, *Carbohydr. Polym.*

2. **James N. BeMiller**, (Book Review) Comprehensive Natural Products Chemistry. Vol. 3. Carbohydrates and Their Derivatives Including Tannins, Cellulose, and Related Lignins, B.M. Pinto, ed., Elsevier Science, Oxford, 1999, *J. Nat. Prod. (Lloydia)*

3. **Duy-Phong Pham-Huu**, Mária Petrušová, **James N. BeMiller**, and Ladislav Petruš, Behaviour of the primary nitro group under denitration conditions, *J. Carbohydr. Chem*.

4. **James N. BeMiller**, Polysaccharides, *in* Encyclopedia of Life Sciences, Macmillan Reference Ltd., London.

5. **James N. BeMiller**, Plant cell walls: economic significance, *in* Encyclopedia of Life Sciences, Macmillan Reference Ltd., London.

6. **James N. BeMiller**, Monosaccharides: occurrence and significance in nature, *in* Glycoscience: Chemistry and Chemical Biology, Springer-Verlag, Heidelberg, Germany.

7. **James N. BeMiller**, Oligosaccharides: occurrence and significance in nature, *in* Glycoscience: Chemistry and Chemical Biology, Springer-Verlag, Heidelberg, Germany.

8. **James N. BeMiller**, Polysaccharides: occurrence and significance in nature, *in* Glycoscience: Chemistry and Chemical Biology, Springer-Verlag, Heidelberg, Germany.

9. **Xiaohong Shi** and **James N. BeMiller**, Effect of sodium sulfate and sodium citrate on derivatization of amylose and amylopectin during hydroxypropylation of corn starch, *Carbohydr. Polym.*

10. **Duy-Phong Pham-Huu, James N. BeMiller**, Mária Petrušová, Ladislav Petruš, Peter Köll, and Jürgen Kopf, A novel and efficient method for preparation of *C*-(1$\rightarrow$2)-disaccharides by the nitromethane methodology: *C*-glycosyl mimetics of 2-*O*-(β-D-mannopyranosyl)-D-glucose, *J. Organic. Chem.*

11. **O.H. Campanella,** P. X. Li, **K.A. Ross**, and M.R. Okos, The role of rheology in extrusion, *Proc. Int. Conf. Eng. Food, ICEF8,* Puebla, Mexico.

12. **A. Aboubacar** and **B.R. Hamaker**, Low molecular weight soluble starch and its relationship with couscous stickiness. *J. Cereal Sci.*

13. **B.R. Hamaker** and B.A. Larkins, Maize food and feed: a current perspective and consideration of future possibilities, *in* Transgenic Crops, Marcel Dekker, Inc., New York.

14. **R.P. Millane**, X-ray fiber diffraction analysis. International Tables for Crystallography, Vol. B, U. Shmueli, ed., International Union of Crystallography.

15. **M. Cornec** and **G. Narsimhan**, Adsorption and exchange of beta lactoglobulin onto spread monoglyceride monolayers at the air-water interface, *Langmuir*

16. **M. Cornec**, **D. Cho,** and **G. Narsimhan**, Adsorption and exchange of whey proteins onto spread lipid monolayers, *in* Emulsions, Foams and Thin Films, K. L. Mittal and P. Kumar, ed.

17. **G. Narsimhan**, Foam fractionation of proteins, *in* Encyclopedia of Separation Science.

C. Manuscripts Submitted (in review process)

1. **P. Cornillon,** W.L. Kerr, and D.S. Reid, A cost effective capacitance meter for food applications, *J Food Eng.*

2. **P. Cornillon,** W.L. Kerr, and D.S. Reid, Mobility changes and dielectric properties of fruits, vegetables and carbohydrate solutions, *J. Food Eng.*

3. P. Veillard**, P. Cornillon,** and R. Stroshine, A NMR study on whole oranges and orange juice. I. Effect of pulp content and concentration, *J. Sci. Food Technol.*

4. J.E. Shin, **P. Cornillon**, and L.C. Salim, Viscoelastic properties and water mobility of agar/sucrose gels, *Food Hydrocoll.*

5. **Y.R. Kim** and **P. Cornillon**, Effects of temperature and mixing time on molecular mobility in wheat dough, *Lebens. Wiss.-Technol.*

6. **P. Cornillon**, A NMR and DSC study of the osmotic dehydration kinetics of apple, *Lebens. Wiss.-Technol.*

7. **P. Cornillon** and L. Salim, Characterization of water mobility and distribution in low-and intermediate-moisture food systems, *Mag. Res. Imaging*

8. **G. Zhang** and **B.R. Hamaker**, Free fatty acids affect sorghum (*Sorghum bicolor* L. Moench) flour pasting properties, *J. Agric. Food Chem.*

9. **X.Z. Han** and **B.R. Hamaker**, Functional and microstructural aspects of soluble starch in pastes and gels, *Starch/Staerke.*

10. **B.A. Bugusu** and **B.R. Hamaker**, Improvement of sorghum-wheat composite dough rheological properties and breadmaking quality through zein addition, *Cereal Chem*.

11. **R.P. Millane** and **J.L. Eads**, Diffraction by one-dimensional paracrystals and perturbed lattices, *Acta Crystallogr*.

12. **Duy-Phong Pham-Huu**, Mária Petrušová, **James N. BeMiller**, and Ladislav Petruš, Behaviour of the primary nitro group under denitration conditions, *J. Carbohydr. Chem.*

D. Papers Presented at Meetings and Conferences and Invited Lectures

1. **B.R. Hamaker**, Corn proteins – functionality, Nabisco, Inc., Fairlawn, New Jersey, January.

2. **B.R. Hamaker**, Studies on the chemical basis of corn masa textural quality, Frito-Lay, Inc., Plano, Texas, January.

3. **B.R. Hamaker**, Effect of protein on cooked rice texture, Rice Utilization Workshop, Little Rock, Arkansas, March.

4. **James N. BeMiller**, Those useful gums and starches, National Center for Agricultural Utilization Research, ARS, USDA, Peoria, IL, March.

5. **James N. BeMiller**, Starch granule anatomy and the future of starch modification, National Center for Agricultural Utilization Research, ARS, USDA, Peoria, IL, March.

6. **James N. BeMiller**, Interactions of starches with salts, surfactants, and other starches, National Center for Agricultural Utilization Research, ARS, USDA, Peoria, IL, March.

7. **J.L. Eads** and **R.P. Millane,** Diffraction by the ideal paracrystal, American Crystallographic Association Annual Meeting, Buffalo, New York, May.

8. **J.L. van der Plas** and **R.P. Millane,** Improved density modification algorithms for *ab initio* macromolecular phasing, American Crystallographic Association Annual Meeting, Buffalo, New York, May.

9. **B.R. Hamaker**, **A. Aboubacar**, **M.B. Miklus**, and **Y.P. Lin**, Amylopectin and lower MW branched starch structures related to starch gel and processed product texture, Frontiers in Carbohydrate Research, West Lafayette, May.

10. **Osvaldo Campanella**, The role of rheology in food processing, Frontiers in Carbohydrate Research, West Lafayette, May.

11. **G. Narsimhan**, Rheology of xanthan gum solutions, Frontiers in Carbohydrate Research, West Lafayette, May.

12. **Paul Cornillon**, Application of modulated differential scanning calorimetry to carbohydrate mixtures, Frontiers in Carbohydrate Research, West Lafayette, May.

13. **James N. BeMiller**, Influence of starch granule architecture on granule reactivity, Frontiers in Carbohydrate Research, West Lafayette, May.

14. **R. Chandrasekaran,** Molecular morphologies and their correlation to functional properties of food polysaccharides, IFT Annual Meeting, Chicago, July.

15. **Y.R. Kim**, and **P. Cornillon**, The effects of gelatinization and mixing time on dough properties, IFT Annual Meeting, Chicago, July.

16. **P. Cornillon**, and A. Huraut, NMR investigation of osmotic dehydration of fruits, IFT Annual Meeting, Chicago, July.

17. **J. Ying**, and **P. Cornillon,** Determination of molecular dynamics and state diagrams in ice cream and its model solutions, IFT Annual Meeting, Chicago, July.

18. **G. Zhang** and **B.R. Hamaker**, Interaction among starch, protein, and lipid affects starch pasting properties, IFT Annual Meeting, Chicago, July.

19. **D.A. Kim**, **M. Cornec**, F. Carvallo, and **G. Narsimhan**, Effect of partial denaturation on the interfacial and emulsification properties of β lactoglobulin, IFT Annual Meeting, Chicago, July.

20. **D.A. Kim** and **G. Narsimhan**, Effect of gamma-irradiation on the interfacial properties of model proteins, IFT Annual Meeting, Chicago, July.

21. **James N. BeMiller**, Food gums and starches: properties and functionalities that arise from structure, IFT Annual Meeting, Chicago, July.

22. **James N. BeMiller**, Carbohydrates and the food industry in the new millenium: an overview, IFT Annual Meeting, Chicago, July.

23. **J.L. van der Plas** and **R.P. Millane**, An algorithm for ab initio electron density reconstruction in macromolecular crystallography, IUCr International Congress of Crystallography, Glasgow, Scotland, August.

24. **R.P. Millane, J. van der Plas,** and **S. Baskaran**, Image reconstruction in x-ray crystallography: some new developments, Image and Vision Computing New Zealand 1999, Christchurch, New Zealand, August.

25. **R.P. Millane**, Image recovery problems in crystallography, Department of Electrical and Electronic Engineering, University of Canterbury, Christchurch, New Zealand, August.

26. **R.P. Millane**, Bayesian MMSE estimates from partial image and spectral data: An application in crystallography, Department of Electrical and Electronic Engineering, University of Canterbury, Christchurch, New Zealand, August.

27. **James N. BeMiller**, Chemistry and our food, American Chemical Society Annual Meeting, New Orleans, August.

28. D.S. Reid, K. Kotte, and **P. Cornillon**, The effect of solute and of freezing interface velocity on the dendrite spacings between ice crystals, International Institute of Refrigeration, Australia, September.

29. **R.P. Millane**, Image recovery: applications in crystallography and optical imaging, Institute of Fundamental Sciences, Massey University, Palmerston North, New Zealand, September

30. **R. Chandrasekaran,** Structure-function correlations in industrially useful polysaccharides, Kusatsu Retreat, Tokyo University of Agriculture and Technology, Tokyo, Japan, October.

31. **James N. BeMiller**, Applications of biopolymers, Central Massachusetts Section, American Chemical Society, Worcester, Massachusetts, October.

32. **James N. BeMiller**, Starch: advances in chemistry and applications, Eastern New York Section, American Chemical Society, Troy, New York, October.

33. **James N. BeMiller**, Applications of biopolymers, Northern New York Section, American Chemical Society, Plattsburgh, New York, October.

34. **James N. BeMiller**, Starch: advances in chemistry and applications, Green Mountain Section, American Chemical Society, Burlington, Vermont, October.

35. **James N. BeMiller,** Applications of biopolymers, Maine Section, American Chemical Society, Orono, Maine, October.

36. **R. Chandrasekaran**, X-ray and molecular modeling studies on nucleic acids and polysaccharides: structure-function relationships, Tokyo Area Crystallography Meeting, Showa University, Tokyo, Japan, November.

37. **R. Chandrasekaran,** Structure-function correlations in industrially useful polysaccharides, Osaka Prefecture University, Osaka, Japan, November.

38. **R. Chandrasekaran,** X-ray and molecular modeling studies on nucleic acids and polysaccharides: structure-function relationships, Osaka University, Osaka, November.

39. **R. Chandrasekaran,** Three-dimensional structure of guar gum and molecular modeling of xanthan:guar complex, Japanese Crystallographic Meeting, Kyoto, Japan, November.

40. **A. Aboubacar** and **B.R. Hamaker**, Application of the BCA assay to identify sorghum with high protein digestibility, American Association of Cereal Chemists Annual Meeting, Seattle, November.

41. **A. Aboubacar**, N. Yazici, and **B.R. Hamaker**, Effects of decortication rate on sorghum flour and couscous quality, American Association of Cereal Chemists Annual Meeting, Seattle, November.

42. **A.S. Tandjung**, **S.J. Batterman-Azcona**, and **B.R. Hamaker**, The effect of corn zein protein on extrudate properties and viscosity profiles, American Association of Cereal Chemists Annual Meeting, Seattle, November.

43. **B.A. Bugusu** and **B.R. Hamaker**, Effect of added zein protein on composite flour dough mixograph curves, American Association of Cereal Chemists Annual Meeting, Seattle, November.

44. **X.Z. Han** and **B.R. Hamaker**, Function of soluble starch in paste viscosity and paste and gel microstructure, American Association of Cereal Chemists Annual Meeting, Seattle, November.

45. **N.C. Mix**, **A. Aboubacar**, and **B.R. Hamaker**, Presence of water-soluble low molecular weight branched starch components in sorghum flour, American Association of Cereal Chemists Annual Meeting, Seattle, November.

46. **M.B. Miklus** and **B.R. Hamaker**, Changes in soluble starch component of masa associated with adhesiveness, American Association of Cereal Chemists Annual Meeting, Seattle, November.

47. **G. Zhang** and **B.R. Hamaker**, Starch-protein-lipid interaction in a model system, American Association of Cereal Chemists Annual Meeting, Seattle, November.

48. **B.R. Hamaker**, **A. Aboubacar**, **M.B. Miklus**, and **N.C. Mix**, Fragmented branched starch structures and product texture, American Association of Cereal Chemists Annual Meeting, Seattle, November.

49. **J.A. Gray** and **J.N. BeMiller**, Access of chemical reagents to starch granules, American Association of Cereal Chemists Annual Meeting, November.

50. **P. Cornillon,** Beyond thermal analysis: The NMR calorimeter, AIChE/CoFE Annual Meeting, Dallas, November.

51. **O.H. Campanella** and M.R. Okos, Transport phenomena in food processing, current and future trends, AIChE/CoFE Annual Meeting, Dallas, November.

52. **A. Bindal**, S. Hem, and **G. Narsimhan**, Effect of steam sterilization on rheology and structure of polysaccharides in solutions, AIChE/CoFE Annual Meeting, Dallas, November.

53. **M. Cornec** and **G. Narsimhan**, Adsorption behavior of whey proteins at air-water interfaces, AIChE/CoFE Annual Meeting, Dallas, November.

54. **D.A. Kim**, **M. Cornec**, and **G. Narsimhan**, Effect of thermal treatment on the interfacial properties of beta-lactoglobulin at oil-water interfaces, AIChE/CoFE Annual Meeting, Dallas, November.

55. **M. Cornec**, **D.A. Kim**, and **G. Narsimhan**, The dynamic absorption of alpha-lactalbumin in native and molten globule state conformation, AIChE/CoFE Annual Meeting, Dallas, November.

56. **A. Bindal**, A. Kulshreshta, S. Hem, and **G. Narsimhan**, Effect of Autoclaving on the Rheology and Structure of Polymer Solutions, American Association of Pharmacy, New Orleans, November.

E. Graduate Degrees Awarded

1. **A. Bindal**, M.S. Effect of Steam Sterilization on Rheology of Polymer Solutions.

2. **P. Goel**, M.S. Effect of Colloidal Forces on Drop Coalescence During Emulsion Formation in a High Pressure Homogenizer.

3. **Mike B. Miklus**, Ph.D. Identification of Novel Starch and Protein Structures Related to Corn Masa Texture.

4. **V. Kurtis Villwock**, Ph.D. Starch Granule Architecture, Water Sorption, and Interactions with Surfactants.

5. **Genyi Zhang**, Ph.D. A Novel Three-way Interaction Among Starch, Protein, and Free Fatty Acid: Functionality and Mechanism Elucidation.

F. Recognitions, Awards, Honors, and Activities

James N. BeMiller, Andrew Jackson Moyer Lectureship, USDA National Center for Agricultural Utilization Research, Peoria, IL.

James N. BeMiller, elected President-elect, American Association of Cereal Chemists.

James N. BeMiller, President, International Carbohydrate Organization.

Osvaldo Campanella, 1999 Outstanding Teaching Award in Engineering, Agricultural and Biological Engineering, Purdue University.

R. Chandrasekaran, invited to be a Visiting Professor for two months (October - December) at Tokyo University of Agriculture and Technology, Japan.

R. Chandrasekaran, invited to be Guest Editor for Vol. 41, No. 3 of *Carbohydrate Polymers.*

Paul Cornillon, Chair of the NMR session on Food Processing at the Conference on Food Engineering.

Jonathan A. Gray, AACC Graduate Fellowship.

Jonathan A. Gray and **Dennis Kim**, members of three-person team that was selected as the Kraft Foods' Grand Prize winner for innovative uses of coffee grounds.

Jonathan A. Gray, member of four-person team that won the Institute of Food Technologists' 1999 Student Product Development Competition for SOY-PRO, a soy protein-based breakfast cereal.

Bruce A. Hamaker, promoted to Professor.

Bruce A. Hamaker, elected Chair-elect and Program Chair of the IFT Carbohydrate Division.

Bridget Ryan Manis, newsletter editor for the IFT Carbohydrate Division.

Rick P. Millane, Sabbatical leave at the University of California, San Diego; University of Canterbury and University of Auckland, New Zealand: April-November.

Rick P. Millane, editor of a feature issue of *Journal of the Optical Society of America.*

Ganesan Narsimhan, chaired technical sessions on Physiochemical Properties of Food Emulsions at the Institute of Food Technologists, Chicago and on Food Emulsions and Foams at the Annual Meeting of the American Institute of Chemical Engineers, Dallas.

Michelle Rzonca, IFTSA Midwest Area Representative.

Kurt Villwock, student representative to the Executive Committee of the AACC Carbohydrate Division, succeeded by **Jonathan Gray**.

Genyi Zhang, Kirleis International Scholarship.

BELFORT LECTURE

The Belfort Lectures were established and endowed by Dr. Anne D. Belfort in memory of her late husband, Dr. Alan M. Belfort, who studied under Professor Roy L. Whistler and was awarded a Ph.D. degree in carbohydrate chemistry in 1960. Belfort Lecturers were originally chosen by the Department of Biochemistry. In 1984, with establishment of the Department of Food Science, the lecture series was transferred there. After establishment of the Whistler Center, lecturers were chosen by it. Persons honored by being chosen to give a Belfort Lecture are scientists who have made outstanding contributions to an area of carbohydrate science.

The 1999 Belfort Lecturer was A.G.J. Voragen, Professor of Food Chemistry, Food Science Department and Director, Department of Food Technology and Nutritional Sciences, Wageningen Agricultural University. Prof. Dr. Voragen's lecture entitled "Progress in Structural Elucidation of Pectin" reviewed work from his laboratory using enzymes and spectroscopic techniques to determine pectin fine structure.

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