SUSTAINING MEMBERS

(Members of the 2000 Industrial Advisory Board)

Cerestar USA

Kellogg Company

Kraft Foods

Nestlé

Penford Corporation

Procter & Gamble

ASSOCIATE MEMBER

Matsutani Chemical Industry

TABLE OF CONTENTS

DIRECTOR'S STATEMENT – 2000

2000 was a year of progress for the Whistler Center. When reflecting on each past year, I use as a yardstick how true we have been to our mission and our **vision** of what the Whistler Center should be, namely, **the premier food carbohydrate research center**, and how well we have met the needs of our customers (our supporting companies, our students, the state, and the country). We, as faculty, students, and staff, are dedicated to achieving our vision by

- **being the leader in research and graduate education related to food carbohydrates,**
- **exhibiting the highest level of creativity and professionalism,** and
- **maintaining successful, productive partnerships with our Sustaining and Associate Member companies.**

Each year the Whistler Center has strengthened its position as the leading academic research center for food gums and starches, and the year 2000 was no exception. We strengthened our core competencies and became a more cohesive unit. Perhaps, most significant of all is the continuing success of our graduated students and former post-doctoral associates, a strong indication of the value and success of our program. Our progress and success is certainly an outgrowth of the fact that we think in terms of the traditional missions of a land-grant university - teaching, research and service – each of which supports the other, and together lead us to higher levels of achievement.

During the year, the Whistler Center conducted an exercise in which each faculty member stated 1, 2 or 3 wishful vision statements of what he would like to be able to do for humankind and/or our field of science. At some point, after we have had time to reflect on and refine the statements, we will share them; but I can say now that they are an indication of the healthy, creative, no-boundaries thinking that permeates the Center.

We are dedicated to expanding understandings and applications of carbohydrate functionalities while solving practical problems. We also, at times, apply our expertise with polysaccharides to other biopolymers, especially proteins, and to non-food applications of gums and starches. Our research is conducted by graduate students and post-doctoral scientists, each of which is learning fundamentals and valuable skills as they solve problems and expand knowledge.

Our commitment to our industrial partners is reflected in our commitment to our focus groups (in which WCCR and company personnel together identify research needs in specific

areas and set priorities) and our follow through. Our goals are to provide value and to exceed expectations.

We make certain that our industrial partners understand that the totality of our research funding, including non-faculty salaries, must be obtained from non-university sources, the primary one being federal agency grants. Having to be competitive in this arena ensures that fundamental, open, cutting-edge research is the core of what we do; but alongside this core are interactions with companies. Because of public funding, we are free to share our new knowledge, even in a confidential way, when necessary, to solve problems. And practical problems often drive our fundamental research, also often being the foundation of, and providing justification for, a basic research proposal.

James N. BeMiller

SUMMARY OF MAJOR RESEARCH ACCOMPLISHMENTS - 2000

Starches and Cereals:

The primary focus of Dr. BeMiller's research group continued to be to determine and control where modification reactions take place in starch granules and on starch polymer molecules. In the course of investigations, it was found via aqueous leaching of hydroxypropylated common corn starches that the more the modification, the easier it is for amylose to leach out and that the preference for leaching of derivatized amylose decreased as the MS of the whole starch increased (Project 7). Likewise, it was found that hydroxypropylation, even at low MS values, markedly increased depolymerization by acid (Project 6).

In a different area of investigation, Dr. BeMiller's laboratory found that gums produce a variety of effects on viscosities of starches during their normal pasting process (increase or decrease greatly or slightly or no effect), phenomena hypothesized to be due to differences in interactions between different amyloses and certain gums (Project 8). In yet another area, it was found that tapioca starch was much more responsive to treatment with protein in the presence of hypochlorite than was common corn, waxy maize, or potato starches. RVA curves of tapioca starch modified in this manner showed significantly reduced breakdown as compared to pasting curves of tapioca starch treated with oxidant alone (Project 3).

Dr. Bruce Hamaker and his students have found that the major internal starch granule protein, granule-bound starch synthase (GBSS), in a waxy maize mutant containing inactivate GBSS, reduced gelatinized paste breakdown compared to an isogenic waxy null line not containing the protein. Also, GBSS increased G′, indicating higher gel/paste strength. These results suggest that internal bound proteins within starch granules play a role in paste texture by increasing the structural integrity of swollen, gelatinized granules. Confocal laser scanning micrographs, using a fluorescent dye active only when associated with protein, revealed GBSS to be concentrated in concentric spheres within the granule (See cover photos). Discrete spheres were most well defined in potato starch, but were also visible, and in higher amount, in maize starch granules (Project 21).

Water Relationships and Thermal Events:

Dr. Cornillon's group has developed and implemented an ultrasound sensor for characterization of frozen foods (Project 30). This sensor will be very valuable in elucidating physical and chemical deteriorations that occur during storage as influenced by freezing conditions. They successfully used modulated differential scanning calorimetry to prove for the first time that the change in heat capacity during gelatinization of starch was not a glass transition, but rather associated with a change in physical state of the starch polymers (Project 34).

Molecular Structures and Properties of Hydrocolloids:

Dr. Chandrasekaran's three papers (Papers A.1, A.2, and A.3) give the complete structural features of three triple-helical nucleic acids for the first time. Modeling studies (Project 14) offered a triple helix as a possible molecular model for an arabinogalactan.

Dr. Millane and his students have further developed models of disordered crystalline systems that are being applied to various polymer systems to characterize both the disorder and the molecular structures (Project 15).

Rheology:

Dr. Campanella's group, via modeling of flaking operations and the flow of dough in dividers, has shown the importance of the rheological properties of the materials in the design of these processes (Project 25). Results have shown that milling conditions as well as mixing time and moisture content affect stickiness of dough (Project 39). They have also found that the porosity of extrudate affected the determined value of the glass transition (Project 26). In collaboration with Dr. Hamaker, rheology was used as a way to identify the effect of shear on the pasting properties of genetically modified starches. (Project 21) Preliminary results from a new project related to the on-line measurement of viscosity using mechanical vibrations clearly showed the potentiality of the proposed method (Paper B.15).

Interfacial Phenomena:

Dr. Narsimhan and his students have quantified the effect of thermal treatment on the conformation of β-lactoglobulin (Project 36). Heating did not significantly alter the secondary conformation of the protein, though an increase in the surface hydrophobicity was detected, thus indicating unfolding of the molecule. The interfacial elasticity and viscosity of the adsorbed protein layer at the oil-water interface were found to change upon thermal treatment. Drop coalescence and emulsion stability measurements for oil-in-water emulsions stabilized by β-lactoglobulin subjected to different heat treatments indicated a strong correlation between emulsion stability and interfacial rheology (Project 37). Span 80, an oil-soluble surfactant, was found to displace β-lactoglobulin from the oil-water interface at sufficiently high concentrations as indicated by a reduction in interfacial rheological properties and emulsion stability.

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FACULTY

James N. BeMiller

GENERAL RESEARCH AREAS

- Carbohydrate chemistry
- Polysaccharide analysis
- Microscopy

SPECIFIC RESEARCH AREAS

- 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
- Light, electron, and confocal microscopy
- Uses of carbohydrates in food and other industries
- Pectin analysis

Osvaldo H. Campanella

GENERAL RESEARCH AREAS

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

SPECIFIC RESEARCH AREAS

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

R. Chandrasekaran

GENERAL RESEARCH AREAS

- X-ray diffraction
- Molecular modeling

SPECIFIC REAEARCH AREAS

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

Paul Cornillon

GENERAL RESEARCH AREAS

- NMR spectroscopy
- MRI
- Freezing phenomena

SPECIFIC RESEARCH AREAS

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

Bruce R. Hamaker

GENERAL RESEARCH AREAS

- Cereal chemistry
- Cereal component functionality and digestibility

SPECIFIC RESEARCH AREAS

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

Rick P. Millane

GENERAL RESEARCH AREAS

- Mathematical and computational modeling
- X-ray diffraction

SPECIFIC RESEARCH AREAS

- Molecular structures, interactions, and dynamics of polysaccharides
- X-ray fiber diffraction analysis
- Theoretical and computational crystallography

- Diffraction by disordered polymer systems
- Statistical mechanical modeling of polymers and gel systems
- Mathematical and computational modeling

G. Narsimhan

GENERAL RESEARCH AREAS

- Emulsions and foams
- Biopolymer interactions

SPECIFIC RESEARCH AREAS

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

Roy L. Whistler

GENERAL RESEARCH AREAS

- Starch chemistry
- Industrial gums

SPECIFIC RESEARCH AREAS

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

ADJUNCT FACULTY

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

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

RESEARCH INTERESTS

- Behaviors of starches and polysaccharides in the presence of other food ingredients

- Molecular basis of functionalities
- Synthesis of biologically active monosaccharide derivatives (collaboration with Drs. BeMiller and Duy-Phong). (Project 4)

GRADUATE STUDENTS

Shyamsunder Baskaran earned a B.S. degree in metallurgical engineering from Indian Institute of Technology, Madras. He joined Dr. Millane's research group in October 1994 and is now in the Ph.D. program. His research project involves new computational methods for locating guest molecules (e.g. counter ions and solvent molecules) in polysaccharide crystal systems. (Project 16) He will complete his studies in 2001.

Wen Bian earned B.E. and M.S. degrees in food science and engineering from Ocean University of Quingdao, China. He joined Dr. Chandrasekaran's group in the Fall of 1997 as a Ph.D. student. His research topic is structure-function correlations of polysaccharides. (Project 12)

Betty Bugusu joined Dr. Hamaker's group in January 1998 to pursue her graduate degrees. Betty comes from the Kenyan Agricultural Research Institute and received her B.S. degree from Egerton University in Kenya in 1991. Betty works on the USAID-funded INTSORMIL project. Her M.S. research focused on improving the functionality of non-wheat proteins in breadmaking systems. She received her degree in May 2000 and is continuing her doctoral work studying slowly digesting starches. (Project 20)

Stephen Christanto obtained two B.S. degrees from Purdue University: Chemical Engineering (May 1998) and Food Process Engineering (May 1999). Stephen, originally from Indonesia, came to the U.S. in 1992 to finish high school and to Purdue in 1994. As an undergraduate, Stephen did bioseparation research in the Chemical Engineering Department under the guidance of Dr. Linda Wang. He joined Dr. Campanella's group for the M.S. program in Food Process Engineering in May 1999. His research deals with dough rheology and the causes of dough stickiness. (Project 27)

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

Jonathan L. Eads earned a B.A. degree, Cum Laude, in Physics from Central College, in Iowa. He was awarded a USDA National Needs Fellowship in 1995 and began study towards the Ph.D. degree in Dr. Millane's laboratory. His research project is concerned with modeling of, and diffraction by, disordered polymer systems. (Project 15) He will complete his degree in May 2001.

Abhishek Goyal earned an M.S. degree in biotechnology from Indian Institute of Technology, Delhi. He joined Dr. Millane's laboratory in August 1998 to pursue a Ph.D. degree. His research project is concerned with modeling and analysis of the myosin lattice in muscle, and simulation of polymer chain configurations in solution. (Projects 15 and 17)

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. (Project 1)

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

Xianzhong Han obtained B.S. and M.S. degrees in plant biology from Hangzhou University in the P.R.C. in 1982 and 1987, and received a second M.S. degree in cereal chemistry from Montana State University in 1996. He joined Dr. Hamaker's lab in January 1998. His Ph.D. research involves a study of the relationship of starch granular and fine structure to functionality. Han will graduate in the Spring of 2001 and will continue with Dr. Hamaker as a post-doctoral Research Associate. (Project 21)

Dennis Kim graduated in May 1998 from Purdue University with B.S. degrees in Biochemistry and Food Process Engineering. As an undergraduate, he was engaged in a Co-Op program with the USDA in their Fermentation Biochemistry Research Unit. Dennis joined Dr. Narsimhan's group in 1997. His Masters' degree research in Food and Bioprocess Engineering involved changes in interfacial and physicochemical properties of model food proteins as a function of their modification. (Project 36) In August, Dennis completed M.S. studies and joined Kraft Foods, where he previously had done a summer internship.

Yong-Ro Kim, who joined Dr. Cornillon's group in January 1998, earned a B.S. degree in Food Science & Technology from Seoul National University, Korea, then worked at Korea Institute of Science and Technology for a year before entering graduate school. He completed his M.S. degree in the Fall of 1997, under the supervision of Drs. Morgan and Okos. His thesis research topic was dielectric properties of baked biscuit dough. His Ph.D. project is the characterization of physicochemical changes in hard wheat flour dough during processing. (Project 32)

Suyong Lee earned B.S. and M.S. degrees in Food Science and Technology from Seoul National University, Korea. His M.S. research involved studying the effect of amylases on the retrogradation and flavor of bread. He joined Dr. Cornillon's group in January 2000 and currently is working on application of NMR and ultrasonic techniques to frozen foods. (Project 30)

Michele Maladen comes from New Delhi, India and holds a B.S. degree in Chemistry from St. Stephen's College, Delhi University. She joined Dr. Hamaker's group in June 2000 to pursue an M.S. degree. Michele is examining the rheological properties and chemistry of the previously identified three-component (starch-protein-fatty acid) complex. (Project 19)

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. (Project 3)

Behic Mert earned a B.S. degree in Food Engineering from Middle East Technical University, Turkey. After working in the bakery industry for two years as food engineer, he began as a Master's degree student at Michigan State University in 1998. His M.S. research involved improving mechanical and barrier properties of whey protein isolate films as a packaging material. He came to Purdue in January 2000 and is now a Ph.D. student of Dr. Campanella. His Ph.D. thesis research involves rheological characterization of materials with acoustical methods. (Project 28)

Nadege Mix earned a B.S. degree in chemistry from University of Bowling Green, Ohio in May 1998 and joined Dr. Hamaker's group that August. Nadege is a native of France. Her M.S. work was on the origin and characterization of a low-molecular-weight, soluble, branched starch component that correlated with product texture. (Project 21) Nadege graduated in August and now holds a position at Kraft Foods.

Belén Prado, from Honduras, began pursuit of an M.S. degree following an internship in Purdue's Food Science department and graduation from Zamarono Pan American School of Agriculture in Honduras. Her research concentrates on the role of soluble branched and linear glucans of differing molecular weights on the textural properties of adhesiveness and cohesiveness. She works under the co-advisement of Drs. Hamaker and BeMiller. (Project 23)

Allison E. Ray earned a B.S. degree in Agricultural and Biological Engineering, with a specialization in Food Engineering, from Purdue. She joined Dr. Narsimhan's group in August 1999 and is working toward an M.S. degree. Her research project involves protein and surfactant interactions and how these interactions work to stabilize emulsions. (Project 37)

Joshua D. Reid joined Dr. Campanella's research group in January 2000. He received a B.S. degree from Purdue University's School of Chemical Engineering in 1995. Subsequently, he entered food research as an M.S. student at the University of Arkansas, where his thesis research involved studying the effects of drying conditions on rice quality. Having completed his M.S. degree in 1998, he interned for a year at Kellogg Company before matriculating in our Ph.D. program. He is the chair of the Student Division of AACC. Joshua's research is focused on developing design methods for dough processing that incorporate the complex rheology of the system. (Project 25)

Kelly Anne Ross joined Dr. Campanella's research group in August of 1999. She earned a B.S. degree with distinction in Food Science in 1996 from the University of Manitoba, and obtained an M.S. degree in Food Science from the same university in 1999. Her Master's thesis research involved studying the texture of french fries from a fundamental mechanics approach. Prior to officially graduating and starting her studies at Purdue, Kelly interned at the Procter & Gamble Company. Kelly's Ph.D. program involves completing courses required to become an ABET accredited engineer while performing research directed towards characterizing the phenomenon of extrudate expansion and the mechanical properties of extrudates. (Project 26)

Michelle Rzonca earned a B.S. degree in Food Science from Purdue University in May 1999. She joined Dr. Cornillon's group in August 1999 and is working toward an M.S. degree. Her research project involves texture determination during fermentation of yogurt made with varying yogurt strains. (Project 29)

Budhi Suhendra worked for much of his undergraduate student years in Dr. Hamaker's lab and, following the completion of his B.S. degree in Food Science from Purdue in May 2000, he entered the M.S. program. Budhi is from Indonesia. His research project is designed to identify ways to achieve high starch digestibility in sorghum grain for animal feed purposes. Dr. Hamaker is his Major Professor. (Project 24)

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

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 focused on correlation of molecular morphology with the functional properties of polysaccharides. (Project 14) Yezhou left the Whistler Center in August.

Agung Tandjung graduated with a B.S. degree in Food Science from Purdue and joined Dr. Hamaker's group in August 1998 in the M.S. degree program. Originally from Indonesia, Agung came to the U.S. in 1995 following a year-and-a-half of study in British Columbia. He recently obtained his M.S. degree on work on the role of corn zein protein in the functionality of breakfast cereal products. His Ph.D. research is focused on popcorn quality. (Project 21)

RESEARCH SCIENTISTS AND ASSOCIATES

Dr. Adam Aboubacar earned a B.S. degree at Kansas State University, then an M.S. degree (1991) at Purdue under the direction of Dr. Allen Kirleis. He joined Dr. Hamaker's research group in 1993 after a return to his home country, Niger. His Ph.D. research project involved determination of starch and grain properties that affect the quality of sorghum-based couscous. He was also involved with setting up an entrepreneurial-scale, couscous processing unit in Niger. Adam was awarded his Ph.D. degree in December 1997, is working as a post-doctoral Research Associate in Dr. Hamaker's lab, and is seeking employment. (Project 22)

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 with Dr. Singh. With Dr. Narsimhan, he investigated the gelation of various systems and the behavior of soybean protein fractions in emulsion systems. (Project 36) Linus left in July to work for Banner Pharmacaps in North Carolina.

Dr. Srinivas Janaswamy earned a Ph.D. degree in 1997 from the Department of Physics, Indian Institute of Technology, Madras. His doctoral dissertation was on the x-ray structural analysis of inorganic compounds in both single crystals and polycrystalline specimens. He joined Dr. Chandrasekaran's group in July 1999 and is conducting x-ray fiber diffraction and molecular modeling studies on industrially useful polysaccharides. (Project 13)

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. She then 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 was involved in a variety of projects involving starch and pectin chemistry and analytical techniques. Dr. Kavitha departed the Whistler Center and returned to India in April.

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

Dr. Jacob van der Plas received a 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, and worked on developing new computational algorithms for protein crystallography. (Project 18) He left the Whistler Center in September to join Crystallics BV in The Netherlands.

Dr. Xiaohong Shi joined our graduate program in 1992, after earning a B.S. degree in polymer physics from the Department of Applied Chemistry, University of Science and Technology of China, and an M.S. degree in the same field at Changchun Institute of Applied Chemistry, Academia Sinica. Nina, as she is known to us, completed Ph.D. requirements in May 1998. Her thesis project under the direction of Dr. BeMiller was self-supporting, edible films. As a post-doctoral Research Associate, she has investigated the chemistry and behaviors of starches using rheological and NMR techniques. (Projects 6, 7, and 8)

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

Dr. Ratchapong (Lek) Wungtanagorn earned a B.S. degree in Agriculture with first class honors and an M.S. degree in Food Science from Kasetsart University, Thailand. His M.S. thesis involved studying the effect of processing on functional properties of calcium caseinate. Lek then worked as an assistant manager of the research and quality control department at United Food Public Co., Ltd., then became an instructor and researcher in the School of Biotechnology, Rangsit University, and then entered the Ph.D. program in Agricultural Engineering with a specialization in Food and Bioprocess Engineering at University of Illinois at Urbana-Champaign. His Ph.D. research was a phenomenological study and mathematical modeling of enthalpy relaxation of sugars. Lek joined Dr. BeMiller's and Dr. Cornillon's groups as a postdoctoral Research Associate in May 2000. His projects involve characterization of fruit products, pectin analysis, thermal analysis of snack products, and mass transfer phenomena using MRI. (Project 31)

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

Dr. Qian Zhang joined Dr. Whistler 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. He worked on starch modification in Dr. Whistler's laboratory, and left for a position at Bio Cryst Pharmaceuticals, Inc. in Birmingham, Alabama in August.

VISITING STUDENTS, SCHOLARS, AND SCIENTISTS

Professor Struther Arnott, Institute of Cancer Research, London, England, and an Adjunct Professor in Purdue's Food Science Department, spent two weeks in Dr. Chandrasekaran's laboratory in June-July, participating in collaborative research on the x-ray structures of nucleic acids.
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Dr. Carlos M. Corvalan was educated in Argentina, where he received a degree in Chemical Engineering from the University of Rosario and a Ph.D. in Computational Fluid Dynamics from the University of Litoral, Santa Fe in 1993. He then joined the faculty of the School of Bioengineering, University of Entre Rios, Argentina. In March 2000, he became a visiting scientist in Dr. Campanella's group. His research interests include modeling of food and biological processes in which interfacial forces play a preponderant role and in flows with free boundaries.

Antje Gonera spent 6 months as an exchange student from the Institute of Food Chemistry, Technical University in Dresden, Germany, being a junior student under the supervision of Dr. Speer (Germany) and Dr. Cornillon. In Dr. Cornillon's lab, Antje studied the glass transition and gelatinization temperatures of starch mixed with gums, sugars, and water using modulated DSC and isothermal NMR relaxometry. (Project 34) She returned to Germany in March.

Jung-Ah Han is a Ph.D. student in Dr. Lim's laboratory. Her research subject is characterizing chain profiles of amylopectins of various origins and their relation to rheological properties of the paste and gel. She is using a multi-angle laser light scattering detector and intermediate-pressure size-exclusion chromatography for the chain structure analysis. (Projects 10 and 11).

Dr. Seung-Taik Lim, a starch scientist and an Associate Professor in the Graduate School of Biotechnology, Korea University, is spending about 9 months in the Whistler Center as a visiting scientist. Dr. Lim is a graduate of Korea University (B.S. and M.S. degrees) and received a Ph.D. degree from Kansas State University in 1990 (Prof. Paul Seib). After doing post-doctoral research at Iowa State University (Prof. Jay-Lin Jane), he joined the faculty of Korea University. His research interests are structural analysis, modification, physical characterization, and utilization of starch polymers. His particular pursuit at the Whistler Center is heat treatments of starches with gums. (Projects 10 and 11).

Professor Tae Wae Moon of Seoul National University, Korea spent six weeks in Dr. Hamaker's lab in January/February as a Visiting Scientist. Dr. Moon's research is on protein-polysaccharide conjugates and other biopolymer structure-function relationships. He and Dr. Hamaker have begun a small collaborative project developed through discussions during his visit.

PROJECT SUMMARIES

Index

1. Title: Channelization of Corn Starch Granules

P.I. J.N. BeMiller
Researchers: Ninik Gunawan, M.S. Student
V.K. Villwock, Ph.D. 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: Objectives 1 and 2: Corn starch granules were gently isolated under non-dehydrating conditions and examined using confocal laser scanning microscopy (CLSM) to gain additional evidence that channels are natural architectural features. (The existence of surface pores and channels in corn and sorghum starch granules had been revealed previously using scanning electron microscopy (SEM) and CLSM.) Channels typically connect starch granule exteriors with the hilum and thus become especially important when considering reactivity. Whether or not the channels are artifactually produced through dehydration had not yet been determined unequivocally, although dehydration was known to expand the center cavity of granules. Common corn starch was obtained from cut kernels which were immediately soaked in mercuric chloride solution to inhibit any amylase activity. Several growth stages were examined. After infiltrating voids within the granule with fluorescent isothiocyanate dextran solution and observing using CLSM, channels were visible in all growth stages. Using transmitted light imaging of non-dyed starch granules, channels were also visible and appeared to breach the granule surface (the surface pores previously observed using SEM). Thus, as with surface pores, it has been demonstrated that channels are natural features of corn starch granules. In addition, it was found that they are present in very early stages of kernel and granule development. This part of the project is completed.

Objective 3: In 1992, we reported the presence of pores on the surface of corn starch granules and suggested that those pores might be openings to channels leading to the interior of granules. In 1993, we published preliminary evidence that there were indeed channels within corn starch granules. In 1997, we presented unequivocal evidence that channels connected the exterior surface of starch granules to the less organized granule interior. In 2000, we presented evidence that the action of enzymes and penetration of reagents during modification of starch for food and industrial use is primarily from the center of corn starch granules outward. During this research, evidence was obtained that, with starch of sorghum, a close relative of corn, the number of pores and channels per granule was under genetic control. We have also reported that the nature of the outer envelope of corn starch granules is under genetic control. These results strongly indicate that the degree of channelization of corn starch granules can be controlled genetically; that is the question to be answered by this research project. A higher degree of channelization would make the starch more valuable, perhaps allowing it to be grown under contract at a premium as is now done with waxy maize, because channels allow access of molecules, including enzymes, to the granule matrix. What would make such corn/corn starch more valuable is more uniform access to modifying reagents used by corn wet milling companies to produce starches for food and industrial applications and greater digestibility of the starch in corn used as animal feed (greater feed efficiency).

Cultivars are being examined on a systematic basis, i.e., first inbred lines, then single crosses of those which are indicated to affect channelization, and so on. Preliminary results from examination of the endosperm mutants *wx, ae, su, du, fl, sh, bt*, has provided supporting evidence that channelization is a function of genetic makeup. Current work focuses on development of a higher-volume, more rapid, more accurate screening technique.

Status: Active.

2. Title: Reaction Sites of Corn Starch Granules
P.I. J.N. BeMiller
Researcher: J. Gray, Ph.D. student
Sponsor: USDA

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

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

One study has been completed; a paper (Paper B.16) is in press. One method (back-scattered electron imaging) for observing granular reaction patterns of modified starch has been developed. One aspect of the current project is to investigate whether 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.

3. Title: Starch Modification with Proteins
P.I.: 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, 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 quantifying the amount of protein remaining in the granules.

The first goals of this project were 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 were varied to obtain the best possible product (characterized by an increase in peak and breakdown viscosity). It was found that the RVA behavior of waxy maize starch can be changed toward that of lightly crosslinked product in this way; but the effect was not dramatic and the efficiency was low. Also, only limited success was obtained with common corn, waxy maize, and potato starches. (Oxidation alone increased peak viscosities and reduced amounts of breakdown during pasting of all. Oxidation, with and without protein, decreased setback in common corn starch. Treated waxy maize and potato starches had slight increases in setback.)

The procedure was then applied to tapioca (cassava) starch (the subject of the 1943 patent). For tapioca starch, including protein in the oxidation reaction significantly reduced breakdown and slightly reduced setback over oxidation alone. In summary, it was found that tapioca starch was much more responsive to the treatment than were the other three starches.

The focus of the project is now on determining 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.

Status: Active.

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

P.I.: J.N. BeMiller

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

Collaborators: L. Petruš, Slovak Academy of Sciences
Y. Gizaw, Procter & Gamble Co.

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

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

carbohydrate mimics. As a part of the project, we also focused our attention on synthesis of D-galactofuranosyl azasugars, which are known as inhibitors of the biosynthesis of mycobacterial cell walls.

Status: Active. A manuscript is under preparation.

5. Title: Relationship of Starch Granule Subpopulations to Reactivity
P.I.: J.N. BeMiller
Researcher: Jonathan A. Stapley, M.S. Student
Sponsor: Available for sponsorship

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

Progress: It is well established that (1) starches from different botanical sources differ in appearance and chemical and physical properties and (2) the population of granules in a given starch preparation is heterogeneous, from some sources more so than others. From this information, it can be hypothesized that there are 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 starch preparation is derivatized. Then, granules are separated by size and each fraction is characterized. Initially, as a model, wheat starch is being used and 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.

6. Title: Openness of Derivatized Starch Granules
P.I.: J.N. BeMiller
Researchers: A.M. Duldulao, M.S. 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: The effects of dilute acid on native and low-substituted (MS *ca.* 0.1) hydroxypropylated common corn, waxy maize, potato and tapioca starches were examined. Susceptibility to acid-catalyzed hydrolysis of these starches derivatized in the presence of sodium sulfate and sodium citrate (as swelling and gelatinization inhibitors during the modification process) was also compared. Definite differences were observed in the rates of hydrolysis of native and hydroxypropylated common corn, waxy maize, potato, and tapioca starches. Results suggest that hydroxypropylation, even at a low degree of substitution, markedly increases either accessibility of the starch granules to aqueous acid and/or susceptibility of the starch polymers to hydrolysis.

Depolymerization of the four modified starches was 2-4 times more rapid than hydrolysis of their native forms. Also, for all modified starches examined, the molar substitution (MS) of the fragments solubilized during the initial stages of hydrolysis was greater (about double) than the molar substitution of the overall starch prior to acid treatment. This suggests that either more open areas within the granules or a sub-population of more highly substituted granules were preferentially attacked by acid. Whether sodium sulfate or sodium citrate was used during derivatization did not appear to affect the rate of hydrolysis. Currently under investigation is whether hydroxypropylation changes the rate of acid-catalyzed hydrolysis of amylose.

Status: Active. Will be completed early in 2001.

7. Title: Effect of Hydroxypropylation on Starch Polymer Leaching
P.I.: J.N. BeMiller
Researcher: X. Shi, Ph.D., Research Associate
Sponsor: Available for sponsorship

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

Progress: Starch fractionation is most often employed to separate amylose from amylopectin. Through fractionation, detailed information, such as the percentage, molecular weight, and branching patterns of each polymeric component, have been obtained. This information is critical to understanding starch structure-functionality relationships and for developing tailored starches via biotechnology. To date, aqueous leaching of amylose from starch granules has only been evaluated by using native starches. Hydroxypropylation is used to decrease starch gelatinization temperature and increase granule swelling, dispersion rate upon cooking, paste clarity, and low-temperature stability of the paste. In this work, aqueous leaching of amylose from hydroxypropylated common corn starch granules (HPCCS, MS *ca.* 0.1) was conducted with time and temperature as variables. Typical results from leaching under optimized conditions were as follows: By the time, two-thirds of the amylose had leached from granules, its purity was only about 90%, and as leaching increased, purity decreased. Hydroxypropylation resulted in more leaching in a given time, but as the MS of the starch increased, the preference for the leached amylose having an even higher MS value decreased. However, the MS of the leached material was constant (and greater than that of the whole starch as previously reported), at least up to the point where two-thirds of the amylose was removed by leaching.

Status: Active. Manuscript in preparation.

8. 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 common corn, waxy maize, and potato starches and the paste viscosity.

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

Pasting curves of starches in gum solutions at low concentrations (starch 3.6%, gum 0.4%) were produced with a Brookfield viscometer. A viscosity increase before the normal starch pasting temperature was detected for common corn starch in the presence of CMC, xanthan, guar gum, and alginate. No such event was observed with waxy corn starch, waxy rice starch, or tapioca starch. Normal rice, potato, and wheat starches gave mixed results. It appeared that interactions between certain amyloses ad certain gums were responsible for the viscosity increase occurring before starch pasting. Gums produced a variety of effects on viscosities of starches during their normal pasting process (increase or decrease greatly or slightly or no effect), phenomena hypothesized to be due to differences in interactions between different amylopectins and different gums.

The pasting peak viscosity of potato starch was greatly decreased by negatively charged gums (CMC, carrageenans, alginate, and xanthan). The repelling forces between the phosphate groups on potato starch and the negative charges on the gum molecules were considered to be the main cause. This hypothesis was supported by results from similar systems (potato starch plus salt solution and phosphorylated common corn starch plus anionic gums), both of which systems also produced lower peak viscosities. It was found by microscopic examination of potato starch heated to 95ºC in a solution of CMC without shear that the gum altered the granule pasting process.

Status: Active. Manuscript in preparation.

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

P.I.: J.N. BeMiller
Researcher: A.M. Duldulao, M.S. Student
Sponsor: Available for sponsorship

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

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

Because there are no crosslinked products that can be used as standards, we have first applied the technique to corn starch modified with inorganic salts so as to produce only a monostarch phosphate product. After determining optimal exchange and washing techniques, metal ion:phosphorus ratios of 1.92-1.96 were obtained. Investigation continues to determine if the method is sensitive to the lower levels of derivatization encountered with commercial crosslinked starches.

Status: Active.

10. Title: Starch-Gum Complex Formation Using Heat Treatments

P.I. S.-T. Lim, Visiting Professor
Researcher: J.A. Han, Visiting Student
Sponsor: WCCR

Objective: Developing new food hydrocolloid/starch-gum composites by heat and moisture treatments.

Progress: Native and hydroxypropylated (HP) starches were heat-treated with various food gums (~1.0% based on starch solids) above 120ºC, either in a sealed container with low moisture (heat-moisture treatment) or in an open container (dry heating). Pasting profiles of the various products were examined using a Rapid Viscoanalyzer. Heat-moisture treatment (HMT) changed the pasting properties of native starches, but not those of HP starches, indicating that hydroxypropylation stabilized the starch granules making them inert to HMT. Some ionic gums produced effects on native corn starch suggestive of crosslinking, i.e., they reduced peak viscosity and stabilized the hot paste to shear. Some treated starches remained unswollen until the temperature reached 95ºC, and paste viscosity continued increasing in the hot stage, resulting in a thick, opaque paste. This trend indicates that covalent bonds could have formed between starch and carboxyl groups of the gums. By controlling gum incorporation and thermal treatment, it should be possible to optimize the physical properties of starch-gum composites to produce new hydrocolloids.

Status: Active, will be presented in the IUFoST meeting in Seoul.

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

P.I. S.-T. Lim, Visiting Professor
Researcher: J.A Han, Visiting Student
Sponsor: WCCR

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

Progress: Previously freeze-dried chains from starch polymer debranching appeared to be degraded by autoclaving (15 – 60 min) or heat-stirring (up to 96 hours in a boiling water bath), based on number-average chain length (CL) determinations. Degradation was more significant with higher amylose contents. Starch chain profiles and weight-average CL changed continuously with heat treatment. Although amylose chains degraded, the

short B-chains became better resolved by the treatment over 24 hours. In addition, some of the short amylopectin chains in debranched waxy starch appeared to aggregate after 12 hours of heat-stirring. Therefore, thermal degradation and molecular dissolution occurred together during heat-stirring, but aggregation seemed to occur when the heat-stirring time was 12 hours or more. For SEC analysis, complete dissolution of starch sample was required. Therefore, starch samples for SEC should be autoclaved, unless alkali or DMSO is used; but for an accurate analysis of chain profiles, heat treatments for sample preparation should be carefully monitored to minimize thermal degradation and to complete starch dissolution.

Status: Active

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

Objective: Determination of the molecular morphology of I886

Progress: X-ray data from oriented fibers of the branched polymer I886 with limited crystallinity have been measured. Molecular modeling calculations confirm that I886 adopts a gellan-like double helix. Two helices are packed antiparallel in a trigonal unit cell. Refinement of the crystal structure is in progress.

Status: Active.

13. Title: Junction Zone Details in Carrageenan Gels
P.I.: R. Chandrasekaran
Researcher: Srinivas Janaswamy, Ph.D., Research Associate
Sponsor: Available for sponsorship

Objective: Determination of the architecture of carrageenan helices and interactions with cations.

Progress: Good diffraction patterns from both sodium and calcium salts of iota-carrageenan have been obtained. Structure analysis of the sodium salt of carrageenan is under way.

Status: Active.

14. Title: Molecular Modeling of an Arabinogalactan
P.I.: R. Chandrasekaran
Researcher: Y. Sun, Ph.D. Student
Sponsor: Available for sponsorship

Objective: Determination of the molecular morphology of larch arabinogalactan.

Progress: Larch arabinogalactan is a water-soluble branched polysaccharide, having low molecular weight and low viscosity with flavor encapsulation and film forming properties. Guided by x-ray diffraction of oriented fibers, and computer modeling, a

probable structure of the polymer is a parallel, 6-fold, right-handed triple helix of pitch 17.6 Å. The side chains stick out of the backbone, giving the arabinogalactan a bush-like appearance.

Status: A paper is being written for publication.

15. Title: Modeling and Analysis of Disordered Crystalline Assemblies
P.I.: R.P. Millane
Researchers: J.L. Eads, Ph.D. Student
A. Goyal, Ph.D. Student
Sponsor: NSF

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

Progress: Crystalline polymer and other macromolecular assemblies often exhibit disorder in the way that the molecules pack together. Two commonly used models of disorder are the paracrystal and the perturbed lattice. We have shown for one-dimensional systems that with an appropriate generalization of the paracrystal model, the two models are essentially identical (Paper A.16). It is observed experimentally that crystallites that are more disordered are generally smaller. We have shown that an interpretation of the "spiral paracrystal" accounts quantitatively for this phenomenon (Paper A.17). Current work is concerned with studying x-ray diffraction properties of the "ideal paracrystal", a model commonly used to describe the disordered packing of polymer molecules in two dimensions.

We have also been studying the disordered myosin lattice that occurs in some types of muscle. We have begun developing a statistical model of this interesting kind of disorder. Future work will involve completing and validating this model, and studying its x-ray diffraction properties.

Status: Active.

16. Title: Methods to Locate Guest Molecules in Crystalline Polymer Fibers
P.I.: R.P. Millane
Researcher: S. Baskaran, Ph.D. Student
Sponsor: NSF

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

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

Status: Active.

17. Title: Monte Carlo Simulation of Polymers in Solution
P.I.: R.P. Millane
Researcher: A. Goyal, Ph.D. Student
Sponsor: Available for sponsorship.

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

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

Status: Active.

18. 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 fewer experimental data.

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. These methods have been applied to simulated x-ray data from spherical viruses at medium resolution with some success. Plans are to apply the methods to proteins with lower symmetry.

Status: Awaiting new personnel.

19. Title: Three-component Complex Among Starch, Protein, and Free Fatty Acids – Its Chemistry and Rheology
P.I.: B.R. Hamaker
Researcher: M. Maladen, M.S. student
Sponsor: Available for sponsorship

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

Progress: Recently, through the doctoral thesis research of G. Zhang, we identified a three-component complex formation involving amylose, free fatty acid, and soluble protein that

resulted in a 2-3 fold increase in RVA cooling-stage paste viscosity. The complex was partially characterized by size-exclusion chromatography and its molecular weight was estimated to be about 1 million Daltons. The mechanism of interaction was also 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. The complex appears to be stabilized by intermolecular disulfide bonds and electrostatic forces. In more recent work, we have optimized the ratios of the components to achieve an isolation of the complex at about 90% purity. It is stable to freeze-drying and has been recovered in large enough amounts to conduct rheological and functional testing.

Status: Active.

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

P.I.: B.R. Hamaker
Researcher: B. Bugusu, Ph.D. student
Sponsor: U.S. Agency for International Development/INTSORMIL

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

Progress: In a previous study (Zhang and Hamaker, *Cereal Chem*. 75:710-713), we showed that starch digestion rate in cooked sorghum flour porridge was notably lower than the rate using maize. Slow digestion rate was related to the protein matrix in the flour as isolated cooked sorghum starch was as digestible as maize starch and proteolysis or disruption with reducing agents increased digestion rate. Yet, it was unclear why starch digestion rate of cooked sorghum flour is slower than that of other cooked cereal flours. This study is just beginning and initially will test the hypotheses that faster digesting sorghum protein, as in a high protein digestibility mutant we previously identified, will result in more digestible starch; that a denser protein matrix in sorghum may reduce the extent of its starch gelatinization, and that extrinsic factors such as phenolic compounds may inhibit digestion.

Status: Active.

21. Title: Influence of Kernel Constituents on the Texture of Corn- and Sorghum-based Products.

P.I.: B.R. Hamaker
Researchers: A. Tandjung, M.S. student
N. Mix, M.S. student
X. Han, Ph.D. student
Sponsors: Kellogg Company (A.T.), U.S. Agency for International Development/INTSORMIL (N.M.), Open (X.H.)

Objectives: (1) Determination of the role of corn α-zein protein in texturization of extruded corn products. (2) Investigation of the origin of, and further characterize, a previously identified low-molecular-weight, branched starch component that highly correlates to cooked sorghum couscous texture. (3) Investigation of 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 specific mechanical energies beginning at about 100 kJ/kg. In this final year of this project, the effect of zein on extrudate texture was tested in a model system consisting of purified corn gluten meal (containing zein in protein body form) and corn starch with and without added unrefined corn oil. Extrudates were conditioned at three moisture levels. Addition of zein was found to increase brittleness of extrudates conditioned at an intermediate moisture content of about 12% and to increase the glass transition temperature of the extrudates.

Status: Completed.

Progress: Obj. 2) In this final year of this project, we investigated further the role of molecularly fragmented starch on product stickiness. Past work on starch fractions related to sorghum couscous texture showed a soluble low-molecular-weight (appearing on a SEC profile at MW below the amylose peak) branched starch component that highly correlates ($r = 0.89$) with cooked couscous stickiness. Milling was identified as the major cause of fragmentation, and detailed characterization of soluble material from milled flours and isolated starches showed the possibility of either or both low-molecular-weight, branched amylopectin fragments and soluble linear glucans participating in the creation of a sticky product. Chromatographic patterns from ball-milled sorghum flours and isolated starches were different, suggesting that the starch damage was different. Higher amounts of starch fragmentation caused linear increases in gel stickiness.

Status: Completed.

Progress: Obj. 3) This year of the project focused on the role of granule-bound starch synthase (GBSS) on starch paste texture and breakdown. ExSeed Genetics provided us with isogenic waxy maize lines both with GBSS absent (typical waxy) and GBSS present, but inactive so that no amylose was synthesized. In rheological tests (up and down shear sweeps), waxy starches containing GBSS were shown to be more resistant to paste breakdown than was typical waxy starch. The loss modulus (G′) was also greater in the waxy starches with GBSS, showing greater gel/paste strength. These experiments indicate that GBSS, which is the major protein found internally in starch granules, contributes to the structural integrity of swollen, gelatinized starch granules, and suggests that efforts to increase amounts or to introduce other proteins within the granule could act to modify pasting characteristics of waxy starches. Confocal laser scanning microscopy was also used to show the internal placement of GBSS in maize and potato starch granules. GBSS was found to exist primarily in discrete, concentric spheres that most likely coincide with amorphous regions of high amylose concentration (Micrographs are shown on the cover of this Annual Report.)

Status: Active.

22. Title: Understanding the Basis of Variability in U.S. Rice Quality by means of Studies of Genotypic and Environment-Induced Variation in Starch Structure

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

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

Progress: Only initial work was done on this new project. Twenty rice varieties were obtained from a collaborating breeder at the University of Arkansas. Texture tests were completed and amylopectin fractions were isolated by size-exclusion chromatography. A multiangle laser light scattering (MALLS) detector was installed and set up in conjunction with an HPLC system and intermediate-pressure columns for analysis of molecular weight profiles of native amylopectin/amylose and debranched amylose linear chains.

Status: Active.

23. Title: Stickiness and Cohesiveness as Related to Dextrin Fine Structure and Size

P.I.s: B.R. Hamaker/J.N. BeMiller
Researcher: B. Prado, M.S. student
Sponsor: Available for sponsorship

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

Progress: This is a new project with an initial focus on finding ways to obtain relatively narrow-molecular-weight dextrin fractions with different branching profiles. Once achieved, rheological testing for stickiness and cohesiveness will establish general structure-function relationships.

Status: Active.

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

P.I.s: B.R. Hamaker
Researchers: B. Suhendra, M.S. student
C.P. Huang, Research Assistant
Sponsor: U.S. Agency for International Development/INTSORMIL (partial)

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

Progress: The initial direction of this project is to attempt to relate differences in protein digestibility in normal sorghum genotypes to differences in starch digestibility. Transmission electron microscopy of developing seed tissues of high-protein-digestibility mutant and normal lines showed that, in the mutant, abnormally-shaped protein bodies form immediately during synthesis, and appear to coalesce during maturation. This would possibly provide a rapidly digesting matrix surrounding starch granules that would result in more available starch.

Status: Active.

25. Title: Computer-aided Design of Cereal Processes

P.I. O.H. Campanella
Researcher: Joshua Reid, Ph.D. student
Sponsor: MAFMA and Cummins Eagle

Objective: (1) Characterization of the geometry of major equipment involved in the main operations of dough processing (auger, dough developer, metering pumps, manifold and forming die). (2) Using commercial CFD (Polyflow) packages, incorporate rheological models that describe the behavior of dough. A liquid model (power-law) will be initially used. Models including viscoelastic effects will be tested following the solution of the power-law model. (3) Determination of strain and stress profiles of the current process and other potential processes involving more complex geometries, notably extrusion.

Progress: Dough processing is moving to a new era of automation and dough mechanical properties need to be maintained within narrow ranges for proper control. Dough processing involves operations such as mixing, transport, and metering, under which the material is subjected to stresses and deformations of different types and magnitudes. Basically, these unit operations apply mechanical energy to the dough, contributing to its development and having a large influence on its rheological properties and the quality of the final product. Thus, in order to solve engineering problems associated with dough processing, we should have an understanding and a quantitative description of how dough rheological properties change due to, and during, the process. Therefore, there is a need for tracking dough deformation and stress as dough travels through the process (e.g., augers, dough developer, metering pumps, forming dies). Dough is a viscoelastic material with properties highly dependent on the ingredients used for its manufacture, notably flour and water, and operating conditions such as temperature, mixing, and shear. Considerable efforts over many years have been employed for understanding of dough rheological properties, how they are related to the flour and ingredients used in its manufacture, processing conditions such as mixing, molding, dividing and sheeting, and properties of the final product. Most of the research, however, was conducted using laboratory-scale equipment and has focused on providing characterization of dough systems, rather than on their interaction with processing equipment and processes. Following the traditional approach, combinations of ingredients, processing conditions, and alternative processes out using pilot or industrial-scale trials could be done. This approach, however, has several drawbacks and could lead to very lengthy and expensive research with little chance of success in the short term. Computer simulation and modeling is an emerging alternative that could be used for understanding, describing, and analyzing dough processing. It has already been used in other industries and saved millions of dollars in research and manufacturing costs by allowing testing of the

performance of a product or process without the construction of a prototype. The modeling of food process involving rheologically complex materials is still at an early stage, and application of rheological data collected on dough has not found widespread utility in the development and design of equipment.

Status: Active.

26. Title: A Systematic Approach to Cereal Processes Development
P.I.: O. H. Campanella
Researcher: Kelly Anne Ross
Sponsor: Available for sponsorship

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

Progress: Processing of cereals involves operations such as mixing, heating, extrusion, puffing, and drying, where raw materials are subjected to stresses, deformations, and moistures and temperatures of different magnitudes. These operations have a large influence on the material rheological properties and the nutritional and textural properties of the final product. The influence of raw material variability and processing conditions on the prediction of final product quality is one of the challenges and long-term goals of the cereal processing industry. This project focuses on the rheological and physicochemical characterization of materials (raw material and final product). This characterization is not only used as material properties of the process simulation research program (Project 25), but also as a mean of characterizing the physicochemical changes of the material upon cereal processing (e.g., flaking, puffing) that affect final product texture, functionality, and nutritional properties. Results of this research will provide a method to predict the effect of processing conditions, notably flaking and puffing, on the overall quality of processed cereal. The systematic approach utilized will be of long-term value to other processes used by the cereal industry.

Status: Active.

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

Objective: Determination of the actual cause of dough stickiness.

Progress: (1) A rheological method for measurement of stickiness has been fine-tuned to a specific application. (2) 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 of stickiness is underway.

Status: Active.

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

Objective: (1) Develop and expand the relevant portions of acoustic theory that describe the interrelationships between the rheological and acoustical properties of foods through numerical modeling and simulation. (2) Construct a bench-top viscometer that uses the principle of acoustic resonance and conduct the experiments necessary to refine the models developed in Objective 1 for the no-flow condition. (3) Construct an in-line viscometer that uses the principle of acoustic resonance and conduct the experiments necessary to refine the models developed in Objective 1 for laminar and turbulent flow conditions.

Progress: The hoped for, long-term outcome of the proposed research is development of an in-line viscometer for foods based on the principle of acoustic resonance (Paper B.15).

Status: Active.

29. Title: Relationship between Texture and EPS Content During Yogurt Formation
P.I.: P. Cornillon
Researcher: Michelle Rzonca, M.S. student
Sponsor: Available for sponsorship

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

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

Status: Active.

30. Title: Importance of Glass Transition on Storage Stability of Frozen Foods
P.I.: P. Cornillon
Researcher: Suyong Lee, Ph.D. student
Sponsor: Purdue Research Foundation and World Food Logistics Organization

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

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

Status: Active.

31. Title: Kinetics of Osmotic Dehydration of Foods
P.I.: P. Cornillon
Researcher: Lek Wungtanagorn, Ph.D. Research Associate
Sponsor: Available for sponsorship

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

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

Status: Active.

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

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

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

Status: Active. A manuscript has been accepted for publication (Paper B.1).

33. Title: Prediction of the Glass Transition of Multicomponent Systems by Group Contribution Theory
P.I.: P. Cornillon
Sponsor: Available for sponsorship

Objectives: (1) Develop a model based on a group contribution theory for predicting the glass transition temperature of common biopolymers and food components. (2) Prediction of the glass transition temperature of multicomponent systems. (3) Compare the predicted data to experimental values obtained by thermal analysis.

Progress: The glass transition temperature is of primary importance when studying the storage stability of food products. However, predictions are commonly erroneous due to the difficulty in accounting for interaction parameters between food components and water. By using a group contribution theory to biopolymers, such parameters could be accounted for to improve predictions of the glass transition of complex food systems.

Status: Non-active.

34. 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) Separation of the "glass transition" event from the gelatinization peak. (2) 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 so-called "glass transition" event during gelatinization was almost simultaneous to the gelatinization peak temperature. Further investigations have demonstrated that the change in heat capacity before and after gelatinization is associated only with a change in the physical state of the system rather than being a true glass transition.

Status: Active. A manuscript has been submitted.

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

Objectives: (1) Determination of the effect of microwaves on the structural and textural properties of frozen foods. (2) 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 coefficients. A correlation between these parameters will be studied to determine the effect of processing.

Status: Under development. Seeking a development partner.

36. Title: Effect of Thermal Treatment on the Interfacial Properties of Beta-Lactoglobulin at Oil-Water Interfaces
P.I.: G. Narsimhan

Researcher: Dennis A. Kim, graduate student
Linus Fonkwe, Research Associate
Sponsor: Available for sponsorship.

Objectives: (1) Investigation of the effect of heat treatment on the conformation of β-lactoglobulin. (2) Investigation of the effect of heat treatment on the interfacial rheological properties of the adsorbed layer of β-lactoglobulin at the oil-water interface. (3) Investigation of the effect of heat treatment of β-lactoglobulin on the stability of oil-in-water emulsions.

β-Lactoglobulin (BLG) solutions at pH 7 were heated at 80°C for various times up to 30 min. There was no significant change in the secondary structure upon heating as inferred from circular dichroism studies. However, the surface hydrophobicity of BLG, as measured from the fluorescence of 1-8-ANS probe bound to hydrophobic patches, was found to increase with heating times, thus indicating a change in the tertiary conformation. This loss of tertiary conformation upon heating led to an increase in the area occupied by a protein molecule at the air-water interface as measured by spread monolayer isotherm using a Langmuir trough. The interfacial shear storage modulus (G′) and shear interfacial viscosity (η) at the *n*-tetradecane/BLG solution interface was measured for native as well as heated samples. G′ and η values were found to be higher for heated samples. The evolution of number concentration of *n*-tetradecane-in-water emulsions stabilized by native and heated BLG samples as monitored by turbidity indicated a higher coalescence rate for the former as compared to the latter. This was consistent with the experimental values of average coalescence times of single n-tetradecane droplets at the *n*-tetradecane-BLG solution interface for native and heated samples.

Status: Active.

37. Title: Effect of Protein-Surfactant Interactions on Interfacial Rheology and Emulsion Stability
P.I.: G. Narsimhan
Researcher: Allison Ray, Graduate Student
Sponsor: Available for sponsorship

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

In many food and pharmaceutical formulations, a mixture of surfactant and protein is employed. Surfactants reduce the interfacial tension, thereby facilitating formation of emulsions and foams with reduced energy consumption. Proteins, on the other hand, form a cohesive interfacial adsorbed layer, thus providing shelf life through enhanced interfacial rheology, as well as steric repulsion between adsorbed layers. It is important to understand the competitive adsorption of proteins and surfactants at interfaces as it relates to emulsion/foam stability. This research focuses on β-lactoglobulin and its interactions with Tween 20, a water-soluble surfactant, at the air-liquid interface and Span 80, an oil-soluble surfactant, at the liquid-liquid interface. The effects of pH and surfactant concentration on protein displacement at air-water and oil-

water interfaces are characterized via interfacial rheological (elasticity and viscosity), surface or interfacial tension, and coalescence stability measurements. The interfacial elasticity, as well as viscosity, was found to decrease with an increase in surfactant concentration for Tween-20 and Span 80. At sufficiently high surfactant concentrations, interfacial rheological properties approached those for pure surfactant systems, thereby indicating complete displacement of protein by the surfactant. Similar behavior was observed at pH values of 5.5 and 7. Measurement of coalescence times of single droplets at planar oil-water interfaces stabilized by a mixture of β-lactoglobulin and Span 80 showed that drops were most stable for pure protein systems. Drop coalescence times decreased with an increase in Span concentration. These results seem to reveal that interfacial rheology improves coalescence stability in this system.

Status: Active.

PUBLICATIONS AND OTHER SCHOLARLY ACTIVITIES

A. Papers, Books, and Book Chapters Published

1. **R. Chandrasekaran, A. Giacometti,** and **S. Arnott**, Structure of poly (dT)•poly(dA)•poly (dT), *J. Biomol. Struct. Dynamics,* 17 (2000) 1011-1022.

2. **R. Chandrasekaran, A. Giacometti,** and **S. Arnott**, Structure of poly(U)•poly(A)•poly(U), *J. Biomol. Struct. Dynamics,* 17 (2000) 1023-1034.

3. **R. Chandrasekaran, A. Giacometti,** and **S. Arnott**, Structure of poly(I)•poly(A)•poly(I), *J. Biomol. Struct. Dynamics,* 17 (2000) 1035-1045.

4. **Kerry C. Huber** and **James N. BeMiller,** Channels of maize and sorghum starch granules, *Carbohydr. Polym*., 41 (2000) 269-76.

5. **James 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, 2000.

6. **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.,* 43 (2000) 333-6.

7. **James N. BeMiller,** Classification, structure, and chemistry of polysaccharides in foods, *in* Handbook of Dietary Fiber and Functional Foods, S.S. Cho and M. Dreher, eds., Marcel Dekker, New York, 2000.

8. **Duy-Phong Pham-Huu,** Mária Petrušová, **James N. BeMiller,** and Ladislav Petruš, Behaviour of the primary nitro group under denitration conditions, *J. Carbohydr. Chem.,* 19 (2000) 93-110.

9. **P. Cornillon** and L. Salim, Characterization of water mobility and distribution in low-moisture foods, *Mag. Reson. Imag.,* 18 (2000) 335-341.

10. **P. Cornillon**, Characterization of osmotic dehydrated apple by NMR and DSC, *Lebensm. Wiss.* -

Tech., 33 (2000) 261-267.

11. **A. Aboubacar** and **B.R. Hamaker**, Low molecular weight soluble starch and its relationship with sorghum couscous stickiness, *J. Cereal Sci*., 31 (2000) 119-126.

12. **C.P. Huang**, E. Hejlsoe-Kohsel, **X.Z. Han**, and **B.R. Hamaker**, Note: Proteolytic activity in sorghum flour and its interference in protein analysis. *Cereal Chem*., 77 (2000) 343-344.

13. **M.P. Oria**, **B.R. Hamaker**, J.D. Axtell, and **C.P. Huang**, A highly digestible sorghum mutant cultivar exhibits a unique folded structure of endosperm protein bodies, *Proc. Natl. Acad. Sci. USA*, 97 (2000) 5065-5070.

14. **X.Z. Han** and **B.R. Hamaker**, Functional and microstructural aspects of soluble corn starch in pastes and gels, *Starch/Staerke*, 2-3 (2000) 76-80.

15. C.M. Weaver, A.C. Mason, and **B.R. Hamaker**, Food Uses, *in* Designing Crops for Added Value, American Society of Agronomy, Madison, WI, 2000.

16. **R.P. Millane** and **J.L. Eads**, Diffraction by one-dimensional paracrystals and perturbed lattices, *Acta Crystallogr.,* A56 (2000) 497-506.

17. **J.L. Eads** and **R.P. Millane**, The crystallite size-disorder relationship based on the spiral paracrystal, *Acta Crystallogr.*, A56 (2000) 549-553.

18. **M. Cornec** and **G. Narsimhan**, Adsorption and exchange of β-lactoglobulin onto spread monoglyceride monolayers at the air-water interface, *Langmuir*, 16 (2000) 1216-1225.

19. **G. Narsimhan**, Foam Fractionation of Proteins, *in* Encyclopedia of Separation Science, Academic Press, Orlando, FL, 2000, pp. 1513-1520.

20. **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, eds., Marcel Dekker, New York, 2000, pp. 293-311.

21. H. Zheng, M.P. Morgenstern, **O.H. Campanella**, and N.G. Larsen, Rheological properties of dough during mechanical dough development, *J. Cereal Sci.*, 32 (2000) 293-306.

B. Papers and Book Chapters in Press

1. **Y.R. Kim** and **P. Cornillon**, Effects of temperature and mixing time on molecular mobility in wheat dough, *Lebensm. Wiss. -Tech*.

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

3. **A. Aboubacar**, J. D. Axtell, **C.P. Huang**, and **B.R. Hamaker**, A rapid protein digestibility assay for the identification of highly digestible sorghum lines, *Cereal Chem*.

4. **X.Z. Han** and **B.R. Hamaker**, Amylopectin fine structure and rice starch paste breakdown, *J. Cereal Sci.*

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

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

7. P. Neogi and **G. Narsimhan**, On Oswald ripening of oil-in-water microemulsion, *Chem. Eng. Sci*.

8. L. Levine, **C.M. Corvalan**, **O.H. Campanella**, and M.R. Okos, A model describing the calendering of finite width sheets, *Chem. Eng. Science*

9. M. Budiman, R. Stroshine, and **O.H. Campanella**, Stress relaxation and low field proton magnetic resonance studies of cheese analog, *J. Text. Studies*

10. **O.H. Campanella** and M. Peleg, Squeezing flow viscometry for liquid and semi liquid foods, *Critical Rev. Food Sci.*

11. **O.H. Campanella** and M. Peleg, Comparison of a new and the traditional method to calculate microbial survival during thermal processing, *J. Sci. Food Agric*.

12. **O.H. Campanella**, P.X. Li, **K.A. Ross,** and M.R. Okos, The role of rheology in extrusion, *in* Engineering and Food for the 21st Century, J. Welti-Chanes, G.V. Barbosa-Canovas, and J.M. Aguilera, eds., Technomic Publishing.

13. B. Hoffner, **O.H. Campanella**, M.G. Corradini, and M. Peleg, Squeezing flow of a highly viscous incompressible liquid pressed between slightly inclined lubricated wide plates, *Rheologica Acta*

14. **J.D. Reid**, **C.M. Corvalan**, L. Levine, **O.H. Campanella**, and M.R. Okos, Sheeting/rolling of finite width sheets. Estimation of final sheet width and the forces and power exerted by the rolls, *Cereal Foods World*

15. L.A. Zimmer, T.A. Haley, and **O.H. Campanella**, A comparative study on the performance of selected in-line viscometers to test the viscosity of Newtonian and non-Newtonian fluids, *J. Text. Studies*

16. **Jonathan A. Gray** and **James N. BeMiller,** Accessibility of starch granules to fatty acylamides, *Cereal Chem*.

C. Manuscripts Submitted (in review process)

1. **R. Chandrasekaran** and G. Stubbs, Fibre diffraction, *in* International Tables for Crystallography, Volume F: Macromolecular Crystallography, M.G. Rossmann and E. Arnold, eds.

2. **J.E. Shin, P. Cornillon**, and L.C. Salim, The effect of centrifugation on agar/sucrose gels, *Food Hydrocoll*.

3. **P. Cornillon,** Imaging and relaxation study of the osmotic dehydration of grapes, *Mag. Reson. Imag.*

4. **P. Walter** and **P. Cornillon,** Influence of thermal conditions and additives on fat bloom study of chocolate, *J. Am. Oil Chem. Soc.*

5. **P. Walter** and **P. Cornillon,** Fat and water migration in chocolate systems, *Food Res. Int.*

6. **P. Cornillon**, W.L. Kerr, and D.S. Reid, Rapid determination of transition temperatures by capacitance measurements, *J. Food Eng.*

7. N. Dawkins, J. Gager, **P. Cornillon**, **Y.R. Kim**, A. Howard, and O. Phelps, 2000. Comparative studies on the physicochemical properties on hydration behavior of oat gum and oatrim in meat-based patties, *J. Food Sci.*

8. P. Veillard, **P. Cornillon**, and R. Stroshine, Effect of soluble and insoluble solids on NMR properties of orange juice, *J. Sci. Food Technol.*

9. **J.H. Auh**, **Y.R. Kim, P. Cornillon**, and K.H. Park, Cryoprotecting mechanism of highly concentrated branched oligosaccharides, *J. Food Sci.*

10. K.H. Jung, R.L. Stroshine, P.M. Hirst, and **P. Cornillon**, Effects of watercore and internal browning on low field (5.35 MHz) proton magnetic resonance measurements of T_2 values of whole apples, *J. Sci. Food Agric.*

11. M. Budiman, R.L. Stroshine, and **P. Cornillon,** Moisture measurement in cheese analog using stretched and multiexponential models of the magnetic resonance T_2 decay curve, *J. Dairy Res.*

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

13. **M. Cornec**, **D. Kim,** and **G. Narsimhan,** Adsorption dynamics and interfacial properties of α-lactalbumin in native and molten globule state conformation at air-water interface, *Food Hydrocoll.*

14. **G. Narsimhan** and **P. Goel**, Drop coalescence during emulsion formation in a high pressure homogenizer for tetradecane-in-water emulsions stabilized by sodium dodecyl sulphate, *J. Coll. Interface Sci.*

17. P.P. Singh, D.E. Maier, and **O.H. Campanella**, Effect of temperature and moisture on dynamic viscoelastic properties of soybeans, *Trans. ASAE*

D. Papers Presented at Meetings and Conferences and Invited Lectures

1. **R. Chandrasekaran,** X-ray results on structure-function correlations in "cellulose-like" polysaccharides, American Chemical Society annual meeting, San Francisco, California, March.

2. **R.P. Millane**, Native cellulose crystal structures through the decades, American Chemical Society annual meeting, San Francisco, California, March.

3. **James N. BeMiller,** Food chemistry of carbohydrates, ACS Wilson Dam Section, Florence, AL, March.

4. **James N. BeMiller,** Applications of biopolymers, ACS Alabama Section, Birmingham, AL, March.

5. **James N. BeMiller,** Applications of biopolymers, ACS Auburn Section, Auburn, AL, March.

6. **James N. BeMiller,** Applications of biopolymers, ACS Ole Miss Section, Oxford, MS, March.

7. **James N. BeMiller,** Food chemistry of carbohydrates, ACS Mississippi Section, Alcorn State, MS, March.

8. **O.H. Campanella**, New Development in Food Extrusion, 67th Annual Food and Dairy Industries Conference, The Ohio State University, April.

9. **O.H. Campanella**, The role of rheology in extrusion, 8th International Conference in Engineering and Food, Puebla, Mexico, April.

10. **O.H. Campanella**, H. Sumali, C.M. Arrick, and R.D. Howard, Measuring viscosity of liquids using vibration signals, 8th International Conference in Engineering and Food, Puebla, Mexico, April.

11. **R.P. Millane** and **A. Goyal**, Aspects of difference Fourier synthesis and the muscle superlattice, 9th Annual Fiber Diffraction and Non-Crystalline Diffraction Workshop, Sheffield, U.K., June.

12. **Ladislav Petruš,** Jozef Turjan, Bożena Pribulová, Erika Lattová, **Duy-Phong Pham-Huu,** and **James N. BeMiller**, Recent advances in the nitromethane modification of saccharides, XXIVth Conference of Organic Chemists, Piestany, Slovakia, June.

13. N.L. Dawkins, J.V. Gager, **P. Cornillon**, O. Phelps, A. Howard and Y. Kim, Hydration behavior of cardiac muscle surimi in meat patties, Institute of Food Technologists annual meeting, Dallas, TX, July.

14. N.L. Dawkins, J.V. Gager, **P. Cornillon**, O. Phelps and A. Howard, ^{1}H-NMR studies on cooked and uncooked meat-based patties, Institute of Food Technologists annual meeting, Dallas, TX, July.

15. **Y.R. Kim** and **P. Cornillon,** Changes of physicochemical properties of wheat flour dough during resting, Institute of Food Technologists annual meeting, Dallas, TX, July.

16. **M.H. Rzonca**, **Y.R. Kim** and **P. Cornillon,** The effects of freezing and changing pH on relaxation times of yogurt, Institute of Food Technologists annual meeting, Dallas, TX, July.

17. **P. Cornillon**, Phase transitions in foods analyzed by NMR, Institute of Food Technologists annual meeting, Dallas, TX, July.

18. **R.P. Millane,** Aspects of disorder in fiber diffraction analysis, American Crystallographic Association annual meeting, St. Paul, Minnesota, July.

19. **J.L. van der Plas** and **R.P. Millane**, New algorithms for *ab inito* macromolecular phasing, American Crystallographic Association annual meeting, St. Paul, Minnesota, July.

20. M. Budiman, R. Stroshine, **O.H. Campanella, P. Cornillon,** and S. Nielsen, Rapid measurement of moisture content of process cheese and cheese analog using low-field proton magnetic resonance, American Society of Agricultural Engineers annual meeting, Milwaukee, July.

21. **James N. BeMiller,** Starch modification as influenced by granule anatomy, Plant Polysaccharides 2000, Wageningen, The Netherlands, August.

22. Bożena Pribulová, Mária Petrušová, **James N. BeMiller,** and Ladislav Petruš, Acid-catalyzed methanolysis of some sugar nitronates, 20th International Carbohydrate Symposium, Hamburg, Germany, August.

23. **Duy-Phong Pham-Huu,** Mária Petrušová, **James N. BeMiller,** Ladislav Petruš, Peter Köll, and Jürgen Kopf, *C*-Glycosyl mimetics of 2-O-(β-D-mannopyranosyl)-D-glucose, 20th International Carbohydrate Symposium, Hamburg, Germany, August.

24. **Yonas Gizaw, Duy-Phong Pham-Huu,** Ladislav Petruš, and **James N. BeMiller,** A simple synthesis of *C*-glycofuranosyl compounds, 9th Bratislava Symposium on Saccharides, Smolenice, Slovakia, September.

25. **P. Cornillon,** Physical property changes of hydrocolloid gels after freezing/thawing, 5th International Hydrocolloids Conference, Raleigh, NC, September.

26. **A.D. Duldulao, J. N. BeMiller,** and **X. Shi,** Effect of hydroxypropylation on rates of acid-catalyzed hydrolysis of granular starch, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

27. **X. Shi** and **J. N. BeMiller,** Aqueous leaching of amylose from hydroxypropylated common corn starch granules, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

28. **B. R. Manis** and **J. N. BeMiller,** Modification of starches with proteins, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

29. **V. K. Villwock** and **J. N. BeMiller,** Channels in common corn starch granules are natural architectural features, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

30. **N. M. Gunawan** and **J. N. BeMiller,** Genetic control of channelization in corn starch granules, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

31. **A.S. Tandjung**, J.S. Marks, and **B.R. Hamaker**, Effect of added zein and crude corn oil on the physical properties of corn starch extrudates, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

32. **C.P. Huang** and **B.R. Hamaker**, Microstructural study of peripheral cells of developing normal and high protein digestibility mutant sorghum cultivars, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

33. **A. Aboubacar** and **B.R. Hamaker**, A new turbidity assay rapidly and efficiently identifies highly digestible sorghum cultivars, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

34. **N.C. Mix**, **A. Aboubacar**, and **B.R. Hamaker**, Origin of a water-soluble carbohydrate fraction related to couscous stickiness, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

35. **X.Z. Han**, **O.H. Campanella**, and **B.R. Hamaker**, Effect of residual proteins in isolated corn starches on the rheological properties of pastes and gels, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

36. **G. Zhang** and **B.R. Hamaker**, Detection of a three-component complex among starch, protein, and free fatty acid, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

37. **B.A. Bugusu** and **B.R. Hamaker**, Effect of added zein on properties and microstructure of sorghum-wheat composite flour dough and bread, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

38. **X.Z. Han** and **B.R. Hamaker**, Correlation of fine structure of amylopectin and starch granule protein with the rheological properties of rice starch pastes, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

39. **B.R. Hamaker**, **X.Z. Han**, and **O.H. Campanella**, Effect of starch granule-associated proteins on rheological properties of corn and rice starch pastes, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

40. M.A. Baker, **O.H. Campanella**, and M.R. Okos, A constitutive model for wheat flour doughs, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

41. **J.D. Reid**, **C.M. Corvalan**, **O.H. Campanella**, and M.R. Okos, Finite element modeling of a dough divider, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

42. **J.D. Reid**, **C.M. Corvalan**, **O.H. Campanella**, and M.R. Okos, Finite element methods for dough equipment design and analysis, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

43. B. Willis, M.R. Okos, and **O.H. Campanella**, Effects of variations in raw materials and processing on rheological properties of pasta-type products, American Association of Cereal Chemists annual meeting, Kansas City, MO, November.

44. **P. Goel** and **G. Narsimhan,** Drop coalescence during emulsion formation in a high pressure homogenizer, American Institute of Chemical Engineers annual meeting, Los Angeles, CA., November.

45. **G. Narsimhan**, Protein adsorption at interfaces, Department of Chemical Engineering, Vanderbilt University, TN, November.

GRADUATE DEGREES AWARDED

1. **B.A. Bugusu**, M.S. Effect of added zein on properties and microstructure of sorghum-wheat composite flour dough and bread.

2. **N.C. Mix**, M.S. Origin and role of fragmented starch in couscous and porridge stickiness.

3. **A.S. Tandjung**, M.S. Effect of added corn zein on texture of starch-based model system extrudates.

RECOGNITIONS, AWARDS, HONORS, AND ACTIVITIES

1. **Bruce Hamaker** received the 2000 Agricultural Research Award from the Purdue School of Agriculture.

2. **Yong-Ro Kim**, First Prize winner of the Procter & Gamble Life Science Award, Spring 2000.

3. **Jonathan Gray** received an AACC Graduate Fellowship.

4. **Jonathan Gray** is President-elect of the IFT Student Association and will become the President in June 2001.

5. **Joshua Reid** began a term as Chair of the AACC Student Division in November.

6. **Paul Cornillon** was the team leader of an interdisciplinary group from three departments that won a Purdue University Materials Consortium award for "Acquisition of a small-volume NMR probe and a FTS cooler for studying phase transition in food, agricultural and pharmaceutical materials".

7. **G. Narsimhan** Chaired the session on "Emulsions and Foams" at the American Institute of Chemical Engineers annual meeting, Los Angeles, CA, November.

8. **J.N. BeMiller** began a term as President of the American Association of Cereal Chemists in November.