Final Report, June 30, 2010

Major Research Contributions from the Department Grain Science and Industry to the Field of Grain Science and Grain Processing

Kansas State University, being a land grant institution, has the responsibility to be engaged in the discovery of knowledge, the education of undergraduate and graduate students, and the delivery of service to the public by disseminating research findings and providing opportunities for life-long learning. Research has been conducted in our Department for a century, and one may ask, “What noteworthy discoveries have occurred?” A group of retired faculty affiliated with the Department, namely D.S. Chung, C.W. Deyoe, R.C. Hoseney, G.L. Lookhart and P.A. Seib, has produced a list of major contributions below. The list was derived from an estimated one thousand publications from the Department in the form of journal articles, reports and reviews, books, and patents. Except for the contributions numbered 1 and 7 below, two criteria were used to make the selections; (1) the findings had to be first-rate science, and (2) they had to lead to a new or improved product or process in a grain-based industry. The seven major contributions are written below in boldface type, and each is followed by some explanatory notes.

1. Seven Hundred and Eight MS and PhD Graduates from the Department

Research on the handling and milling of wheat and its quality in 1910 prompted the founding of the Department of Milling Industry, Kansas State Agricultural College. The first graduate student was Ms. Leila Dunton who received the MS degree in 1911. Her work describing the effects of storing, handling, and germination of wheat on its composition and milling and baking quality was published in Technical Bulletin No.1 of the Kansas Agricultural Experiment Station. Ms. Dutton’s thesis was mentioned in the 1929 historical document on the Department written by Charles O. Swanson. Apparently, some theses and reports dating between 1910-1924 have been lost, perhaps due to the 1957 fire that destroyed most of the departmental facilities. In the present collection of theses in the Resource Room of our Department, the first thesis on the shelf is a 1924 MS thesis by Wilbur E. Watkins, which is titled “A Study of Gluten Quality as Affected by Varying Reactions on Both Sides of the Isoelectric Point”. C. O. Swanson was the major professor. The Graduate School at KSU was formed in 1932, and the first doctoral thesis from the Department was authored by Royce O. Pence and is titled “Flour Mill Flow Sheets Analysis”. Again, C.O. Swanson was the major professor. We now count a total of 513 MS and 317 PhD theses published in the Department by 708 graduate students. The research results in those theses added critical knowledge to the field of grain science since only a few public institutions around the world house research workers in our field.
In addition, those 708 students came from one-fourth of the countries in the world (52 of 194). A majority of our alums returned to their home countries where they became leaders in government, academia, and industry. In their leadership positions they helped establish the global reputation of our Department.

2. Milling and Baking Quality of Hard Winter Wheat

The first faculty members in our Department recognized that wheat improvement encompasses not only gains in crop yield, but also improvements in quality for end-use. Laboratory methods were devised to evaluate the milling and baking qualities of hard winter wheats, which included chemical methods to measure composition, physical methods to measure dough mixing, and bench-scale bread-making tests, such as the pup-loaf baking test that starts with 100-g flour. In 1937 the U.S. Department of Agriculture established the Hard Wheat Quality Laboratory in the Department with the mission of assisting wheat breeders to improve the quality of hard winter wheat. Over the years, collaborative evaluations of newly released wheat varieties by commercial millers and bakers were coordinated by the Department, and written reports were issued and made available to all. Those large-scale evaluations are presently coordinated by the Wheat Quality Council. In the early 1980’s a Wheat Quality Laboratory was started in the Department of Agronomy. That Laboratory is staffed by faculty from our Department, and its mission is to determine which breeding lines from K-State Research and Extension have the proper quality to be released. In the past 25 years, for example, over two-thirds of the wheat crop in Kansas, with a total value over those years of $30 billion, can be attributed to varieties released by K-State Research and Extension. The exporting of hard winter wheat created the need to educate end-users abroad, and many international trade teams were hosted by the Department to learn about the buying/selling of wheat and other grains, and their storage, handling, and processing. The education efforts with respect to exports led to the formation of the International Grains Program to promote the sale of agricultural commodities produced in the Central Plains Region. The key faculty members in this sector of activities include L.A. Fitz, C.O. Swanson, J.A. Shellenberger, E.G. Bayfield, A.B. Ward, K.F. Finney, O.K. Chung, and C.W. Deyoe.

3. Findings from Research in Cereal Chemistry and Value-Added

Around 1910 in the Department, it was discovered that some ammonium salts were beneficial in bread-making. Today, all yeast-leavened bakery foods are made with yeast food that contains ammonium salts. Also during that era, it was discovered that bread dough could be developed rapidly by high-speed mixing, which led to the development of methods to make bread in one-half the time compared to conventional methods. In 1953, B.S. Miller, J.A. Johnson and D.L. Palmer published a journal article in which they showed that bacterial alpha-amylase was a potent inhibitor of crumb firming in bread, although their source of enzyme also caused the bread crumb to be sticky. That work confirmed a claim by S.S. Jackel and coworkers at the 1952 AACC National Meeting that bacterial amylase could be used to retard the staling of bread. Today, so-called
maltogenic alpha-amylase is used to inhibit bread firming for weeks, resulting in huge savings in the cost of delivering bread to the marketplace. In the 1960’s researchers in the Department separated wheat flour into four fractions, with the most abundant fractions being starch, protein and lipids. Those fractions could be combined in the proper proportion to reconstitute a flour, and the reconstituted flour was shown to be equal to the baking quality of the original flour. Then the fractions could be exchanged between flours to determine which fraction(s) controlled different quality attributes of a baked product. Flour protein, for example, was established as the most important component controlling the quality of bread. It was also demonstrated that starch granules in flour remained largely unchanged during the manufacturing of sugar cookies, whereas in bread and soft cake the granules showed an increasing cooked appearance. Wheat lipids were demonstrated to play an important role in bakery foods, and those findings stimulated the development of various surfactants to strengthen bread dough, improve crumb grain, retard crumb firming, spare shortening (fat), and improve high-fiber breads. Dynamic and static rheological instruments were used to measure the viscoelastic properties of doughs and starch gels, and the textures of end-use products. The glass transition temperature, which is the narrow temperature range over which an amorphous solid changes from a glassy (friable) texture to a leathery and rubbery texture, was determined for gluten protein and for wheat starch at different moisture levels. Those results demonstrated that the moisture content of a cereal food plays a major role in its eating texture. Stable forms of vitamin C were produced and tested in foods and animal feed. The 2-phosphate and the 2-polyphosphate ester of L-ascorbic acid were found to be equivalent in vitamin C potency to L-ascorbic acid. Both of those esters were demonstrated to be stable in foods and feeds that lack the enzyme phosphatase. Today the 2-polyphosphate ester is widely used in formulated feeds for aquatic animals. A resistant starch was discovered and patented in 1997. Resistant starch is not digested in the small intestine but is fermented in the large intestine. Resistant starch is included within the definition of dietary fiber, which has been shown to promote gut health. Biodegradable and edible barrels were invented and patented. Those barrels replace steel drums on the range and are used to hold concentrated nutrients for ruminant animals. Biobased adhesives have been formulated for many uses, including straw board, plywood, and pet food. Key faculty members in this sector of activities include C.O. Swanson, K.F. Finney, Y. Pomeranz, B.S. Miller, J.A. Johnson, R.C. Hoseney, C.W. Deyoe, P.A. Seib, O.K. Chung, C. C. Tsen, and X. S. Sun.

4. Findings in the Storage and Milling of Wheat

The safe storage of grain depends in the largest measure on its moisture content. In 1966 D.S. Chung and H.B. Pfost derived a two-parameter equation to predict the equilibrium moisture content of grain at a given temperature and relative humidity. The Chung-Pfost equation is valid in the temperature range of 22-50°C (70-140°F) over the entire range of relative humidities. The equation has been widely used in modeling of grain aeration, drying, and storage studies. In on-farm storage of grain and in terminal-elevator storage
our faculty have collaborated with those in the Department of Entomology to monitor the quality of grain. Heat-treatment of mills and warehouses as a method of pest control has been refined and advanced by faculty in our Department.

Milling research has been done on laboratory mills and on a pilot-scale (200 cwt/8h) mill. Methods were devised to reduce the tempering time of wheat, improve isolation of germ, produce low-speck farina, and to produce flours of extraction rates between 50-85%. Instead of ash-content to measure bran contamination of flour streams, the ferulic acid in bran was used. Since ferulic acid in flour can be assayed by infrared light, it is possible to measure on-line flour purity. In other work the pilot-scale flour mill has been used to follow the location of mycotoxins in mill streams, and software has been written to yield an economic model of the products from a flour mill. In addition, a short-flow bread-flour mill was designed and patented, and a number of those units have been installed around the world.


5. Findings in Feed Milling

During the last half of the past century, a pilot-feed mill was used for research (and teaching) in our Department. The protein and amino acid profiles in many feed ingredients were determined, and least-cost rations were computed by software. Methods to determine uniformities of mixes, and to determine pellet durability were devised. High-temperature, high-shear extrusion was used to produce “Starea”. Starea is a ruminant feed containing a non-protein source of nitrogen that is slowly released in the rumen. The slow release of urea prevents the buildup of toxic levels of ammonia in the animals. A sister product of Starea was made using a hydrothermal process that created a molasses-like fluid called “Star-Lick”. In other research the nutrient requirements of catfish were investigated, and the data included in a publication on fish nutrition by the National Research Council, National Academy of Sciences.

The key faculty members in these activities include C.W. Deyoe and H.B. Pfost.

6. Intellectual Property

The KSU Research Foundation (KSURF) is charged with procuring and protecting intellectual property at KSU. KSURF was founded in 1942 and obtained its first patent assignment in 1944. Since then 217 patents have been issued to the Foundation, of which 140 (65%) have garnered fees or royalties. Faculty members in the Dept of Grain Science have accounted for 51 (24%) of the patents granted to KSURF, and 36 (69%) of the Department’s patents have been licensed. The faculty in the Department represent less than 1% of the total number of faculty in the University.

Since its inception and until 2010, KSURF had collected, if one counts cost-reimbursement fees and royalties, a total of $20,678,741 of which $7,321,667 (35%) is 4.
attributable to the Department of Grain Science and Industry. The 7th patent, (US No 3,642,489) in the KSURF portfolio was issued April 18, 1969 to E. Bartley of the Department of Animal Science and C.W. Deyoe of the Department of Grain Science and Industry, and is titled “Feed Product Containing Non-Protein Nitrogen Compounds and Method for Producing Same.” That patent describing Starea was the first to bring royalty dollars to KSURF.

7. Monographs Authored or Edited by Grain Science Faculty

C.O. Swanson
Physical Properties of Dough, Burgess, 1943
Wheat and Flour Quality, Burgess, 1941
Wheat Flour and Diet, MacMillan, 1928

John Shellenberger, F. Wichser, R.Pence, R.Lakamp-Joint Authors
Flour Granulation Studies, Millers National Federation, 1950

Harry Pfost-Technical Editor
Feed Production Handbook, Feed Production School, 1961

Harry Pfost-Technical Editor
Feed Manufacturing Technology, Editions I & II, AFMA, 1970 & 1976

Y. Pomeranz, John Shellenberger-Joint Authors
Bread Science & Technology, AVI Publishing, 1971

Cho Tsen-Editor
Triticale: First Man-Made Cereal, AACC, 1974

Paul A. Seib and B. L. Tolbert-Joint Editors
Ascorbic Acid: Chemistry, Metabolism and Uses, American Chemical Society, 1982

Robert McEllhiney- Editor
Truck Management, AFMA, 1983
Feed Manufacturing Technology, Editions III & IV, AFIA, 1985 &1994

H. Faridi, Jon Faubion-Joint Editors
Fundamentals of Dough Rheology, AACC, 1986

R. Carl Hoseney

John Wingfield
Directory of Milling Terms, AOM, 1989
H. Faridi, Jon Faubion-Joint Authors
Dough Rheology and Baked Product Texture, Van Nostrand Reinhold, 1989

Finlay MacRitchie
Chemistry at Interfaces, Academic Press, 1990

R. Mills, John Pederson-Joint Authors

H. Faridi, Jon Faubion-Joint Editors
Wheat End Uses around the World, AACC, 1995

Charles Walker, J. Hazelton, M. Shogren-Joint Authors
The Mixograph Handbook, TMCO, 1997

David Wetzel, G. Charalambous-Joint Editors
Instrumental Methods in Food and Beverage Analysis, Elsevier, 1998

R. Hamer, Carl Hoseney-Joint Editors
Interactions: The Keys to Cereal Quality, AACC, 1998

Bhadriraju Subramanyam, D. Hagstrum-Joint Editors
Alternatives to Pesticides in Stored-Product IPM, Kluwer Academic, 2000

K. Kulp, Joseph Ponte-Joint Editors
Handbook of Cereal Science and Technology, Marcel Dekker, 2000

P. Shewry, George Lookhart-Joint Editors
Wheat Gluten Protein Analysis, AACC, 2003

C. Wrigley, H. Corke, Charles Walker-Joint Editors
Encyclopedia of Grain Science, Vol. 1, 2, 3, Elsevier, 2004

R. Wool, Susan Sun-Joint Authors
Bio-Based Polymers and Composites, Elsevier, 2005

Carl Reed
Managing Stored Grain to Preserve Quality and Value, AACC, 2005

D. Hagstrum, Bhadriraju Subramanyam-Joint Authors
Fundamentals of Stored-Product Entomology, AACC, 2006

George Lookhart, P. Ng-Joint Editors
Gluten Proteins, AACC, 2006
D. Hagstrum, Bhadriraju Subramanyam-Joint Authors
Stored-Product Insect Resource, AACC, 2009

J. Delcour, R Carl Hoseney-Joint Authors
Principles of Cereal Science, AACC, 3rd ed. 2010