Critical Reviews:

Progress in all objectives was achieved during the 1993-1997 time period. Considerable progress was made in expansion of the NIR analyzer network. Iowa, Ohio, and Illinois, were joined by Kansas, Nebraska, Indiana, and Texas in making compositional and/or end-use data available for variety performance trials. Progress in ascertaining the biology of fungal contamination of grain and mycotoxin formation was particularly noteworthy, and is evidenced by extensive scholarly publication of research results. (Please see attachment D). Additional discoveries in understanding, detecting and managing insect infestation of stored grains were achieved. Progress in optimization of drying processes, particularly included computer control, is continuing at several stations and research centers.

Publication of research results, due to cross-regional interdisciplinary efforts were achieved as illustrated by publications resulting from e.g. Ohio-NCAUR published in Cereal Chemistry in 1993 and 1994, and by Iowa-Illinois collaborative efforts that resulted in a North-central regional publication by Hill et al.:


Below, some of the accomplishments and impacts from the different objectives are listed. The list does not cover all accomplishments. It is intended to be representative illustrative of the NC-213 committee’s overall efforts.

Objective A

ACCOMPLISHMENTS and IMPACTS: There previously existed little independent data available to both producers and processors regarding grain compositional traits or suitability of commercially available corn hybrids for wet milling, alkaline processing, and dry milling. Since the last renewal, several participants have initiated reporting of grain quality data in performance test publications, and additional programs similar to the Iowa Gold program are being conducted to provide information on selected hybrids. For example, the Nebraska Corn Board in cooperation with Kansas State University, Purdue University, and Iowa State University now make such data available on a web page. Producers, seed corn companies, and processors routinely access these resources. The availability of data is assisted the industry in identifying value and creating new business opportunities.

Iowa State University has the largest database of corn and soybean quality information in the nation. ISU will continue to provide intrinsic quality measurement services for genetic evaluations, outside groups and other situations, but now, with the development of the Iowa Grain Quality Initiative, this data will be organized for national use. ISU will be adding staff to manage the database, assure its scientific validity and implement new interpretive tools (contract assessment, estimation of hard to measure factors, processing value calculations). Any user, producer, geneticist, processor, etc. will be able to access the ISU database, a ready source of information in a form that can be applied and understood.

Sorghum hybrids with improved food and feed quality have been released are produced on a limited basis in Texas. One company in Texas is producing a special diet and ethnic foods from the new hybrids. In Ohio, extension research has assisted producers of new high-oil corn hybrids.
Over 6,000 acres of high-oil hybrids are being produced for Eastern poultry feeders and the research assistance is vital to growers who are using the new genetic technology.

**Objective B:**
**ACCOMPLISHMENTS and IMPACTS:** A significant percentage of the Minnesota hard red spring wheat crop has been infected with the preharvest disease *Fusarium* head blight (scab) the last few years. The disease reduces grain yield and test weight, and can produce mycotoxins. Minnesota research on the storability of scab-infected wheat showed that cleaning the grain on a gravity table would produce a slight improvement in grain storability. But the increase in storability was small enough, that farmers who manage their stored grain well (store at proper moisture and temperature) should not be afraid to store scab-infected wheat. Our results also indicated that levels of the mycotoxin produced by the fungi that cause scab are not likely to increase in storage. This information has been distributed to farmers and grain buyers through press releases, newsletters, and electronic distribution systems.

Nebraska researchers examined the effects of preservatives and fungicides on *Fusarium* growth and mycotoxin production. There is little or no information on the effects of food preservatives, such as propionates, sorbates and benzoates, etc. on growth and mycotoxin production by *Fusarium* species. Also, the fungicide iprodione has been studied as a corn preservative. Nebraska research on the effects of preservatives and fungicides on mold growth and mycotoxin production. The fungicide iprodione has been studied as a preservative for stored corn. Our research on the effects of iprodione on toxigenic molds has shown that at relatively low concentrations (10-20 g/g) iprodione inhibited mold growth and the production of aflatoxin, ochratoxin and cyclopiazonic acid, resulting in added benefits. This information is helping to bring about more orderly marketing of scab-infected wheat and is reducing the losses experienced by farmers who harvest scab-infected wheat.

Many farmers in the upper Midwest have been interested in using ambient-air corn drying to reduce harvest-time labor and to improve quality of their corn, but they have hesitated to try it because they weren’t sure of the risks, or if it would work at all in our cold climate, and they were concerned about energy costs for ambient-air drying. Minnesota researchers conducted a number of modeling studies of ambient-air corn drying using Minnesota weather data and a variety of fan sizes and fan management schemes.

The Minnesota study helped to quantify the risks for ambient-air drying in our climate, and showed some potential ways to reduce energy costs. This information was used to write a University of Minnesota Extension Service bulletin *Natural-Air Corn Drying in the Upper Midwest,* that is now being distributed to farmers and agri-businesses. This bulletin is giving readers a better understanding of the natural-air drying process and helping them to select equipment that provides a good balance between risk of spoilage and energy cost.

In Kansas, forty farmers are practicing an integrated pest management (IPM) strategy using sanitation, aeration, and monitoring to preserve stored wheat quality. Eighteen farmers collaborating in this project shared the with over 600 of their neighbors how the use of low-cost aeration controllers in farm storage bins preserved their wheat quality at 20 field days throughout Kansas. In response to this effort, fewer farmers are applying residual insecticides to their farm-stored wheat.

**OBJECTIVE C:**
**ACCOMPLISHMENTS:**
*Alternatives to chemical insecticides* -- In Minnesota and Montana, alternatives to chemical insecticides have been discovered. Concern about the decreasing number of insecticides registered for use on stored grain, increasing resistance of insects to commonly used insecticides, and effects of insecticides on humans and the environment has led to a demand for non-chemical approaches to
controlling insects. B.H. Subramanyam has conducted research on the use of diatomaceous earth for controlling stored product insects and is publishing results of this work in technical journals (see relevant publications), but is also extending this information directly to educators and to the public. Information on algorithms and criteria for determining corn allowable storage time should be available by winter 1999. This research should provide new, improved methods for determining allowable storage time, or confirm and give us more confidence in existing methods. The Minnesota station also plans to have preliminary information on the storability of white corn compared to yellow corn so that it may be determined whether or not the existing yellow corn data base can be used to estimate storability of white corn. Discoveries of biorational insect control alternatives, using botanically derived chemicals, has resulted in the issuance of several patents. It is hoped that the patenting process will facilitate commercialization of the protects so that they may be more readily brought to the market.

**Spectral Analysis Quality Measurement** - Successful implementation of near infra-red transmittance spectral analysis (NIRT) in the U. S. cereal and oilseed marketing system occurred over the past five years as an outgrowth of the NC-213 project. The near infrared network, begun in Iowa in 1995 and utilizing calibrations developed at Iowa State University is now the largest grouping of such instruments in the US. It is expected that there will be 250 units on line by September 1998.

NC-213 scientists have begun to explore the use of single kernel spectral analysis using near infra-red reflectance technology. The successful incorporation of a fiber optic diode array system occurred in 1996 and this technology became commercially available in late 1997.

Further attempts to explore the use of spectral analysis to promote a quality-based marketing approach for cereals and oilseeds includes investigation into predicting starch recovery in corn, measurement of amylose and protein in rice, and objective classification of wheat.

**Image Analysis Quality Measurement** - Development of image analysis technology for objective measurement of stress crack in corn occurred during the past 5 years. This technology permits rapid (2 sec) single kernel evaluation of physical defects and morphological characteristics that relate to corn end-use quality. Digital analysis of sliced bread now permits scientists to categorize porosity patterns that enable scientists to distinguish different mixtures and water absorption.

**Single Kernel Characterization** - The development of a single kernel characterization system (SKCS) progressed from and experimental prototype to a commercial instrument approved and used by the Federal Grain Inspection Service (FGIS) of the United States to identify wheat hardness for classification purposes. Efforts to use single kernel size, weight, moisture, and hardness data to predict flour extraction and form wheat blends are in progress. Single kernel tests are performed by ARS and University labs for all major public wheat breeding programs in the United States using this technology.

An experimental single kernel pycnometer for measuring wheat kernel density was developed and tested. The instrument, though highly labor intensive, displayed a high level of precision and repeatability. Scab damage kernel possessed the lowest kernel variation between kernel types (health, scab, sprouted) prevented single kernel prediction using the SKCS.

**Processing Quality of Cereals** - NC-213 researchers’ investigations into the alkaline cooking properties of corn revealed the floatation method provided the best predictive information for processing performance.

Stream flaking studies with sorghum confirm that way sorghum flakes possess the largest diameter, greatest flake stability, best appearance, lowest bulk density, and the most tolerance to handling. Tempering grain prior to flaking reduced energy consumption significantly and enhanced the appearance and durability of the flakes. Flour and various mixes from recently
released food sorghum are commercially available and an export market for these cultivars has developed in Africa.

An abbreviated wet-milling process was devised to isolate readily assessable starch from grain sorghum. By-product streams were combined with alfalfa meal and resulted in an improved cattle feed.

An effort to identify specific chemical and physical factors in corn and changes in processing conditions which influence corn wet milling products and yields revealed that absorption during steeping increased with lactic acid use and lower steeping temperatures.

Processing Quality of Oilseeds - Objective evaluation of tofu quality revealed that both variety and storage treatment impact elasticity, cohesiveness, color, and protein extraction properties. Evaluation of organoleptic properties of oil from genetically modified soybeans that possessed lower linolenic acid content were superior to commercial un-hydrogenated soybean oil. Blends and interesterified products of soybean oil and palm oil showed improved stability relative to soybean oil oxicizability. New methodology to identify oil impurities using nuclear magnetic resonance spectral analysis were explored as a mechanism to improve food quality of vegetable oil.

Protein Characterization/Functionality - Work performed of the past 5 years to characterize proteins in cereals and correlate these data with end-use properties has been performed. High molecular weight glutenin sub-units (HMWGS) which are correlated with bread-making quality were characterized for 12 lines of hard red winter and hard red spring wheat. This information will assist breeders in their crossing decisions and selection process. Methodology developed for protein separation reduced analysis time to under 10 minutes using high-performance capillary electrophoresis (HPCE).

An evaluation of soy-heat protein in shrimp feed provided similar growth response and superior pellet durability in water compared to traditional animal protein sources.

Sanitary Quality - NC-213 researchers identified grain odors and their source using gas chromatography and mass spectrometry. This and other developments are leading the way toward an objective evaluation of grain quality deterioration resulting in an odor problem.

Research into the relationship between mold, ergosterol content, and ochratoxin revealed the ergosterol content was a better indicator of the presence of the mycotoxin than mold. A state wide survey in Nebraska revealed that fumonisins was prevalent in the corn corp. A market basket study of corn products throughout the U.S. revealed that fumonisins was prevalent in the U.S. food supply (specifically in corn meal and corn muffin mixes). Evaluation of corn dry milled fractions revealed that the bran contained more fumonisins than the corn grits. Efforts to denature fumonisins using heat treatments and extrusion cooking were partially successful. Research into the presence of deoxynivalenol in corn and wheat in Nebraska was studies, as was the DNA composition of isolates of the causal organisms.

Moisture Measurement - An evaluation of the accuracy of di-electric moisture meters compared to oven-dry moisture contents revealed that most NTEP meters in federal and state labs reported moisture contents slightly below the oven-dry method. The repeatability of most oven-dry and NTEP moisture meters was good in the four elevators monitored in Ohio.

Investigation of rice receiving, drying, and storage on end-use properties reveals that low-temperature dried rice had a significantly greater volume expansion and water expansion that did the high-temperature dried rice. Storage conditions significantly affected starch functionality and sensory properties.
Evaluation of Kansas grain elevators revealed that most commercial facilities could perform segregation during harvest rush. The principal source of wheat quality variation during harvest occurred between producers, followed by wheat varieties, and country elevator location. The impact in Kansas was for commercial elevator operators to become more aware of their operating performance and to improve their performance.

GMPRC selected control strategies will be implemented to achieve automatic control of grain aeration systems over extended wheat and corn storage periods. A microprocessor based data acquisition and control unit will be used to implement the aeration control strategies, control fan operations and record performance data.

These studies can have considerable impact on the quality of stored grain, and producer and handler profitability by revealing how conditions may be optimized.

Mycotoxin contamination of grains -- Nebraska researchers examined effects of processing on molds and mycotoxins in grains. Little information has been available on the fate of fumonisins in contaminated corn that is processed into human food. Most of these food processes involve heating the corn by some means. Their research showed that higher temperatures and dry heat are more destructive to fumonisins than lower temperatures and moist heat, and that fumonisins are very heat stable and can be expected to remain in heat processed food products unless very high process temperatures are used. This information is important because it helps to understand how stable fumonisins are in heat processed food products. In studies on dry milling of fumonisin contaminated corn it was found that most of the fumonisin was transferred to the bran and germ fractions and little or none was found in the flaking and snack grit fractions.

NC-213 researchers also determined and identified factors impacting corn wet milling. Methods were developed to quickly measure, using HPLC, the chemical components in wet milling steep liquor. The impact of lactic acid, sulfur dioxide and temperature on wet milling produce yields was carefully assessed using response surface analysis; this effort validated the appropriateness of current laboratory methods for assessing corn quality for wet-milling product yields, and helped to confirm that the industrial process has been optimized for the current corn types used. Additional analysis was conducted to assess the impact of changing current processing practices, to account for corn quality changes, on the major end-product of wet milling (starch). It appears, within certain ranges, the current industrial process can be slightly modified to account for and optimize production when using most common corn hybrids. These results have given the wet milling industry confidence in their current laboratory starch wet-milling methods, as well as provided analytical tools for the routine measurement of corn steeps. Both of these developments help insure process quality.

IMPACTS:

- Grain handlers and processors throughout the corn and soybean production region of the U.S. adopted this accurate and stable NIR technology for evaluating the chemical composition of corn and soybeans.
- Development and use of mass calibration methodology enabled the cereal and oilseed industry to ensure accurate measurement of corn and soybean chemical constituents using these instruments, thus providing a mechanism for value-added market of these crops to develop.
- Digital analysis of wheat micro-structures (from scanning electron microscope images) enables scientist to differentiate between wheat classes (hard and soft) based on starch granular structures.
• Work with image analysis and neural network software enabled accurate (95%) identification of scabby wheat, hence, facilitating progress toward objective grading of Kernel damage.
• International adoption of single kernel hardness tester has begun, both at a commercial level as well as by official grain inspection agencies.
• Wheat by-products streams are being combined to give an improved cattle feed in Kansas.
• Research results showed how the grain industry could improve profitability and product quality through improved dryer management.
• Research on mycotoxins is dry milling products helped clarify why breakfast cereals and snack foods have been found to be free of fumonisins, helping to reassure the consumer of a safe food product.
• Reduction in feed waste, improved animal performance, increased efficiency of feed mill use, increased market territory, and increased imports of U.S. feed grains.

Objective D:
ACOMPLISHMENTS and IMPACTS:

A series of studies concerning the feasibility of cleaning grains, and of possibly changing the grades and standards were completed. Earlier studies by the ERS to quantify the costs and benefits associated with cleaning wheat had omitted the role of the combine. A cooperative study between T. Herrman, T. Loughin, M. Schrock provided additional information that supported the economic feasibility of cleaning wheat at the country grain elevator.

The NC publication by Hill et al. was completed in 1995.


Studies on the feasibility of isolating high quality grain have now reached the implementation stage. At least one major processor in Iowa will be offering differential payments to producers, based on protein and oil in soybeans. The close relationship with the NIR network provides a large potential to collect research data from industrial situations. It is estimated that in the near future 20% or more of Iowa corn and soybeans will be produced for a specific end use, and that the Iowa projects will have demonstrably contributed to the ability of the market to handle this transition.

RECOGNITION OF ACCOMPLISHMENTS THROUGH EXTERNAL FUNDING OF PROJECTS:

The accomplishments of NC-213 participants have been recognized and rewarded by granting of external funds to support the research objectives. A partial list of specific funding sources is presented below to illustrate the nature of the fund donors:

• CSREES Integrated Pest Management Initiative
• FGIS/ARS; K-State Experiment Station.
• Foreign Agricultural Service Emerging Markets
• Grain Industry Alliance (GIA)
Illinois Dept. of Agriculture
Iowa Corn Growers Association
Iowa Corn Promotion Board
Iowa Soybean Growers Association
Kansas Wheat Commission
Kansas Department of Commerce and Housing Ag. Products
Midwest Advanced Food manufacturing Alliance (MAFMA)
National Corn Growers Association
National Research Initiative Markets and Trade
Nebraska Corn Board
Ohio Soybean Council
Pioneer Hi-Bred International, Inc.
Soybean Research and Development Council
State of Iowa Grain Quality Initiative
USDA-ARS for “Confirmation of carbon dioxide production from samples of shelled corn exposed to changing temperature and equilibrium moisture conditions.” (MN)
USDA/CSREES/NRICGP “Incidence and fate of moniliformin in corn and heat processed corn products.” (NE)
USDA Specific Cooperative Research Agreements with the Ohio State University/OARDC for introgression of value-added traits from Germplasm Enhancement of Maize (GEM) Project populations into elite Corn Belt maize

Neb.
C2a: Determine and identify specific chemical and physical factors in corn and changes in processing conditions that influence corn wet milling and alkaline cooking product yields. The installation of a complete alkaline cooking process line at the University of Nebraska will enable researchers to develop response surface cooking experiments using various kinds of corn and to vary process conditions. It is hoped that cooking procedures can be developed to minimize alkaline cooking waste and to maximize yield for both traditionally “good” alkaline cooking corn hybrids as well as softer corns, currently considered unacceptable. Additional efforts, in the area of wet milling, will focus on determining optimum process conditions for corn that has been improperly dried and/or is otherwise physically damaged. Some results will be available in 1998/99, with additional data available in subsequent year. It is hoped that this information will allow processors to use a wider range of corn hybrids (in both wet milling and alkaline processing) as well as allow processing of corn that has not considered optimum for these processes.

C3b: Methods for detection and quantitation of mycotoxins. We intend to develop a high performance liquid chromatographic (HPLC) method for detection and quantification of moniliformin. These techniques will be needed to study the fate of moniliformin in thermal food processes. Anticipated delivery date May 1998.

Stability of moniliformin in thermal food processes. In this work we will determine the
incidence and concentrations of moniliformin in U.S. corn and corn-based foods. We will also
determine if moniliformin co-occurs with fumonisins. We also intend to study the effect of heat
on the stability of moniliformin in aqueous buffered solutions at different temperatures, pH levels
and heating times and in corn using different selected thermal processes, such as canning, baking,
frying, roasting, extrusion and alkaline processing (tortilla process). Similar studies will be done
with deoxynivalenol and zearalenone. This work will develop more information which will increase
understanding of the stability of Fusarium mycotoxins in processed foods. Anticipated delivery
date September, 1999.

Deliverable

ISU
Uniformity (standardization) remains the primary problem facing the user of this technology. Iowa
projects in this objective will develop and field verify mathematical procedures for simplifying
standardization. There will also be new procedures for routine quality control and for quantifying
the variability of units in the field. Calibration and operating performance criteria will be published
for NIR applications in general. It is also expected that new corn calibrations (amylose, waxy, wet
mill yield, ), soybean calibrations (fatty acids, amino acids, sugars, protein solubility), soybean
meal calibrations (proximate analysis, protein solubility, amino acids) will be added to network
capabilities. It is our intent to become a recognized national standard in grain analysis, and to
develop a chemometrics research center capable of bringing online new generation NIR
technology.