# NC-213

(The U.S. Quality Grains Research Consortium)

# 2021 ANNUAL PROGRESS REPORTS

***Published: March 2022***

## MARKETING AND DELIVERY OF QUALITY GRAINS AND BIOPROCESS COPRODUCTS

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**Illinois** Crop Improvement ..... John McKinney

**Pioneer** ..... Morrie Bryant – 2012-2017

The **Quaker** Oats Company/PepsiCo ..... A. Bruce Roskens

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Please note that it is the responsibility of the author and any co-authors for all editing of their Progress Reports for clarity, spelling, grammar, errors, and other editorial issues.

**NC-213 (The U.S. Quality Grains Research Consortium)**

**Objective 1**

To measure, model, and assess factors which influence quality and safety attributes in the post-harvest usage, drying, handling, and distribution of cereal grains and oilseeds.

## Title

Texas A&M AgriLife Research NC-213 Multi-state Project Report on Marketing and Delivery of Quality Grains and Bioprocess Coproducts.

## By

Herrman, T.J., Office of the Texas State Chemist, Texas A&M AgriLife Research
Lee, K.M.
Li, W.
Brown, A.

Moore, J., Department of Agricultural and Biological Engineering, Texas A&M University

## Outputs

Research scientists collaborated with the USDA ARS Environmental Microbial and Food Safety Laboratory for application of spectral imaging for aflatoxin screening. In this study, multiple hyperspectral imaging techniques with visible and near-infrared (VNIR) system, short-wave infrared (SWIR) system, and Raman spectroscopy were applied for rapid detection and classification of aflatoxins in ground maize. For hyperspectral imaging analysis, the total of 122 naturally contaminated maize samples were collected and scanned to acquire four types of hyperspectral imaging data including fluorescence, VNIR reflectance, SWIR reflectance, and Raman. The averaged spectra of maize sample were preprocessed to remove interference signals using various different preprocessing methods (normalization, Savitzky-Golay, smoothing, standard normal variate, and multiplicative scatter correction) prior to image calibration, spectral extraction, preprocessing, and modeling with MATLAB. Four classification models developed on each hyperspectral imaging mode in combination with different preprocessing methods displayed acceptable classification accuracies of 95.7%, 82.6%, 95.7%, 87.0% for fluorescence, VNIR, SWIR, and Raman, respectively while no false negative error was found at the cutoff of 10 μg/kg. The findings and observations from this study imply that the hyperspectral imaging techniques employed are promising and feasible as simple and inexpensive tools for rapid detection of aflatoxins in maize and grain-based food and feed products.

Consumption of fumonisin-contaminated corn by cattle has been associated with hepatotoxicity, immunotoxicity, and pulmonary edema or hypertension thought to arise following the disruption of sphingolipid metabolism. The study funded by the NC-213 Anderson Grant Endowment administered by the Ohio State University involves managing fumonisin risk in the corn value chain by comparing a Meta-Analysis and Benchmark Dose Approach (BMDA) to address food safety, quality, and marketing systems of Texas cattle. Graduate research student Ashli A. Brown previously developed a PECO statement to identify articles reporting cattle exposure to dietary fumonisin via oral consumption. These studies include Baker and Rottinghaus 1999; Jennings et al., 2020; Osweiler et al., 1993; and Smith and Thakur 1996. During year 1, Ms. Brown has performed a critical analysis on each study and created a BMDA table that categorizes the number of animals, administered dose of fumonisin, and the mean and standard deviation of animal body weight. Due to variations in reported body weight and measurement outcomes, Ms. Brown now explores ways to overcome challenges regarding uncertainty. Following this, Ms. Brown will compare a meta-analysis and BMDA to increase the statistical power and confidence of a newly defined safety breakpoint associated with fumonisin in cattle diets.

Dried Distillers Grains with Solubles (DDGS) are co-products of dry-grind ethanol production used as nutrient-dense and lower-cost alternatives in animal feeds at inclusion rates ranging from 0 to 100%. Highly variable sulfur (S) concentrations in DDGS limit the use in ruminant diets due to an increased risk of polioencephalomalacia (PEM), a neurological condition characterized by cerebrum dysfunction. Published literature associates decreased

risk for PEM with increased levels of effective neutral detergent fiber (eNDF). This research uses a Monte Carlo simulation to evaluate the impact of dietary S in DDGS and eNDF levels on the risk of PEM for feedlot cattle in Texas. Thus far, Ms. Brown has constructed a Monte Carlo simulation to estimate the probability of S toxicity for cattle diets containing a range of 0.11% to 1.1% total dietary S based on a dry matter basis with the assumption that DDGS are the prominent source of sulfur. Results currently reveal the lowest observable effect concentration for total dietary S on S-induced PEM in Texas feedlot cattle is 0.3% diet DM. Findings also indicate that as eNDF levels increased in feedlot cattle diets at a given S concentration, the relative risk of PEM decreased. This suggests that cattle producers and handlers should feed feedlot cattle at higher eNDF levels if the total dietary S concentration varies significantly. For future research, Ms. Brown will also assess the risk of PEM based on rumen degradable sulfur and incorporate protein feeds, energy feeds, and roughage sources as feed ingredient categories to integrate example cattle diets and real-life events.

A screening method for confirmation of 107 pesticides in feed product was developed in OTSC by UPLC-MS/MS and GC-MS/MS. The method was adapted from CLG-PST5.08 and AOAC Official Method 2007.01 with modifications. Brief procedure includes: Samples are extracted using acetonitrile; water is added for low moisture animal feed matrices. Separate portions of the extract are cleaned up for the determination of pesticides by GC-MS/MS and UPLC-MS/MS. This method is suitable for screening the pesticides in feed products at levels above MLAs listed in the table below. The applicability to matrices other than feed may vary and needs to be determined by following appropriate guidelines.

We demonstrated that Atmospheric Cold Plasma (ACP) can effectively treat cowpea weevils. As a result, this novel treatment technology has the potential to be used and aid in grain storage sustainability. Samples of cowpea weevils were treated for 1, 2, and 3 minutes at voltages of 20, 50, and 70 kV. There was little effect for the 20 kV treatments, significant reduction was achieved at 70 kV for all life cycles (eggs, 1st instar, and adults). Eggs treated at 70 kV for 3 minutes had a reduction in emergence rate to 25% from 92% for the control. We achieved an 82% mortality rate in three major developmental phases of the cowpea weevil overall. Although the adult stage was the most resistant to treatment, the predicted mortality rate was still achieved.

## Outcomes/Impacts

A fully developed method based on hyperspectral imaging classification models would be ideal and more efficient over standard wet-chemical methods to reduce the labor and time for monitoring aflatoxin contaminated products. With ongoing developments in optical hardware, hyperspectral imaging techniques and machine learning methods could lead to more accurate and rapid screening of mycotoxin contaminated samples to help prevent mycotoxins from becoming an animal and human health issue. Completion of the fumonisin study will benefit corn producers and cattle producers by providing increased certainty involving risk and the potential economic impact of high levels of fumonisin in the Texas High Plains. The evaluation of sulfur in DDGS and risk assessment better equips the Texas animal feed regulatory risk manager and industry in managing S risk. Improved pesticide analysis better quantifies risk in grain, feed and food products. As a result of work with ACP research, this novel treatment technology has the potential to be used and aid in grain storage sustainability.

## Publications

Kim, Y.K., Baek, I., Lee, K.M., Qin, J., Kim, G., Shin, B. K., Chan, D.E., Herrman, T.J., Cho, S.K., and Kim, M.S. 2021. Investigation of reflectance, fluorescence, and Raman hyperspectral imaging techniques for rapid detection of aflatoxins in ground maize. Food Control. 132:108479.

## Funding Sources

FDA-NIH U19 Lab Flexible Funding Model.

USDA Food Emergency Response Network.

The Andersons Research Grant Program, Administrated by The Ohio State University.

National Science Foundation.

FDA Animal Feed Regulatory Program Standards.

## Opportunities for training and professional development provided by project

Three course offerings on Hazard Analysis and Preventive Controls for Feed occurred during the reporting period. The course participants received certificates from the Food Safety Preventive Control Alliance and the International HACCP Alliance. Participants completed food safety plans using HACCP principles and Food Safety Modernization Act rules through an educational outreach workshop funded by the Food and Drug Administration.

## How have the results been disseminated to communities of interest?

Dissemination of results through a list serve reaching approximately 10,000 regulatory risk managers globally.

## What do you plan to do during the next reporting period to accomplish the goals?

During year 2, Ms. Brown will incorporate the newly defined safety breakpoint and fumonisin concentrations collected in Texas into a Monte Carlo simulation to estimate the financial impact of corn containing fumonisin on Texas corn producers and the feed industry. Ms. Brown intends that this research, in its entirety, will provide a superior understanding of the risk of exposure to excess fumonisin in cattle diets to benefit the production, manufacturing, and labeling of cattle feed ingredients and help estimate future economic losses to the cattle industry. Validate micro-fluidics point of care analysis for fumonisin and aflatoxin contamination and biomarkers involving human exposure in collaboration with Cornell University and Waters/Vicam. AgriLife will collaborate with Cornell to develop a low-cost smartphone-based point-of-need platform for analyzing aflatoxin and fumonisin in maize through validating this testing platform at the OTSC laboratory, the Texas grain industry and at two public health laboratories in Kenya. The proposed assay will help in preventing the food safety violations specifically in resource limited settings, due to its point-of-need attribute.

Publish fumonisin results including economic analysis, risk assessment, field validation, impact of co-regulation in managing risk, methods for testing fumonisin in high moisture matrices, and performance statistics for FGIS method validation.

## Title

Long Term Performance of Near Infrared Transmission (NIR) Analyzers.

## By

Hurburgh, C.R., Professor, Iowa State University
Mosher, G.A., Associate Professor

## Outputs

The Iowa State University grain quality laboratory has been creating corn and soybean proximate analysis calibrations for multiple models of near infrared transmission (NIRT) analyzers for over 20 years. These calibrations have been utilized by the lab in testing submitted samples for internal and commercial users, and by plant breeding and grain market participants for testing purposes. Calibrations are validated by instrument model to reference chemistry on an annual basis. Reproducibility (across copies of the same model) and repeatability (across repeat tests of the same sample in the same instrument model) are tracked, respectively, in the customer instrument standardization and set-up procedures and in the submitted sample testing protocol.

In all cases, calibrations remained accurate for 5-7 years. Reproducibility changed very little over time. The standard deviation across instrument copies was 40-60% of the standard deviation of the calibration equations, relative to the respective chemical references. Repeatability was less than 25% of the standard deviation of the calibration equations. Instruments used in laboratory testing were from the Foss Infratec series, 1225, 1229,1241, and Nova. Factors measured were corn moisture, protein, oil, starch, and density; soybean moisture, protein, oil, and fiber. Primary sources of variation in the model were error and employee variation.

## Outcomes/Impacts

Long-term performance of NIRT units was very consistent, with periodic calibration updates to include recent genetics and environmental conditions. Earlier research demonstrated that instrument accuracy and variability was critical to making economically sound marketing decisions based on the NIRT data. A structured program of calibration and validation must be followed to move component data into the set of routine trading and handling parameters.

## Publications

Barr, B.E., C. R. Hurburgh, and G.A. Mosher. Maximizing Processing Value with Selective Handling Strategies: An Analysis of Soybeans Received at Iowa Elevators. *Applied Engineering in Agriculture*. 37(4): 583-594. doi: http://10.13031/aea.14534

## Funding Sources

Laboratory service fees

United Soybean Board

## Title

Engineering Properties to Characterize Performance of Hermetic Storage Bag Technology.

## By

Maier, D.E., Professor, Agricultural & Biosystems Engineering, Iowa State University
Ignacio, M.C.C.D., Graduate Research Associate, Agricultural & Biosystems Engineering
Bern, C.J., Professor Emeritus, Agricultural & Biosystems Engineering
Rosentrater, K.A., Associate Professor, Agricultural & Biosystems Engineering
Vorst, K., Associate Professor, Food Science and Human Nutrition
Bowers, E.L., Adjunct Assistant Professor, Agricultural & Biosystems Engineering

## Outputs

The impacts of hermetic storage bag technology on food security are well established in several published articles and by the increasing adoption of smallholder farmers in Sub-Saharan Africa and Asia. Though the demand for hermetic storage bags continues to grow, more research is needed to address existing and emerging challenges to improve and expand the supply chain of this storage technology, ensuring the continued success of hermetic storage bags in reducing grain damage and loss, preserving grain quality, and increasing profit of farmers. The research goals of this project focus on the engineering properties to characterize the performance of hermetic storage bag technology. Specific objectives include the follow objectives:

1. Quantify key engineering properties to develop a standard on gas tightness of hermetic storage bags.
2. Estimate the environmental impacts of hermetic storage bag technology.
3. Predict the oxygen depletion during grain storage using hermetic bag technology; and
4. Apply the analytic hierarchy process (AHP) to rank commercially available hermetic storage bag liners.

Outputs for Each Study

1. Characterization of engineering properties of hermetic storage bag technology for standards development

- Quantified key engineering properties of commercially available hermetic storage bag liners, including variables such as tensile strength, dart impact failure weight, tear force, oxygen transmission rate, and water vapor transmission rates. Data will be published as a research manuscript and utilized as the basis and specification for a ASABE Standard Project, as described below.
- ASABE Project X657: *Measurement and rating of hermetic storage bags – Specifications of gas barrier liners*: Dirk Maier (chair) and Cristine Ignacio (co-chair) lead the development committee for an ASABE standard project, facilitating monthly meetings since July 2021. The committee drafts the standard document following ASABE standard development protocols, proactively coordinating with the Kenyan Bureau of Standards and the Eastern African Grain Council.

2. Prediction of Oxygen Depletion in Hermetic Storage Bags

This study developed a spreadsheet summary dashboard and calculator to predict oxygen depletion in hermetic storage bags as a function of insect species, grain respiration, and bag liner properties. Maize oxygen consumption was calculated at several levels of moisture content and temperature using the dry matter loss equation. In contrast, oxygen consumption by maize weevils was calculated as a function of different development stages of the weevil. The oxygen transmission rate of single and double liners was utilized to quantify the gas transmission into the liners

during storage. Results confirmed that insect respiration dominated oxygen depletion in maize stored at safe storage moisture contents of 13-14% while grain and fungi respiration was negligible.

The number of days before oxygen concentration inside the bag reduced below 5% to kill adult insects was determined for several grain moisture and temperature scenarios, insect infestations, and hermetic bag liner types. Results provide an improved understanding of the science behind the hermetic storage bag technology and provided the science to support the successful adoption of this critical storage technology among smallholder farmers. The spreadsheet will be further modified to accommodate other grain types and insect species.

3. Analytical Hierarchy Process in Ranking Commercially Available Hermetic Bag Liners

This study used the analytic hierarchy process (AHP) method as a decision-making tool based on multicriteria analysis for ranking six commercially available hermetic storage bag liner products (AgroZbag, Elite, PICS, SuperGrainbag, Storezo, Zerofly bag) in low-income countries in Sub-Saharan Africa, Central America, and Asia. The method was to take a pairwise comparison of alternatives based on previously defined criteria and sub-criteria, such as key engineering properties, aging properties, and environmental impact. The bag liners were tested for tensile strength, dart impact failure weight, tear force, and permeability (oxygen transmission rate, water-vapor transmission rate) following the American Society for Testing and Materials (ASTM) standard test methods.

The aging experiment was conducted in an environmental chamber set at 35°C temperature and 70% relative humidity to estimate the changes in the liner properties after six months of use. The environmental impacts were assessed using the Sustainable Minds Life Cycle Analysis (LCA) software from cradle to grave. Results provided an analytic approach to rank hermetic storage bag technology products using science-based decision criteria. The global priority values calculated range from 0.14 to 0.20. Sensitivity analysis showed that if a liner has 75% higher OTR and WVTR values, it will have a priority value of 0.05.

4. Performance Analysis of Biological Oxygen Scrubber used in Hermetic Storage Bag Technology

A maize storage experiment using hermetic bags to assess the performance of biological oxygen scrubbers has been initiated. A factorial design with two factors (type of hermetic bag liner and type oxygen scrubber) is considered for the study. The dependent variables tested were grain quality characteristics such as moisture content, test weight, dry matter loss, percent grain damage, and commercially objectionable foreign odor (COFO), aflatoxin content, and the number of insects (alive or dead). The maize samples were initially infested by maize weevils (2 adult insect/kg grain) and placed in an environmental chamber at ~30°C and 70% RH for up to 3 months. Experimentation continues with these variables.

## Funding Sources

The Rockefeller Foundation (Grant #2018 FOD 004)

Foundation for Food and Agriculture Research (Grant # DFs-18-0000000008)

Iowa Agriculture and Home Economics Experiment Station

Foreign PhD Fellowship, UP Faculty, REPS, Administrative Staff Development Program (FRASDP, University of the Philippines (UP), Los Banos, The Philippines

## Publications

Oral Presentations

Ignacio M.C.C.D. and Maier D.E. *"Analytic Hierarchy Process Applied to the Ranking of Commercially Available Hermetic Bag Liners"*, 3rd All Africa Postharvest Congress and Exhibition (Virtual Event), September 13 to 16, 2021 ***(3rd Best Oral Presentation)***

Ignacio M.C.C.D. and Maier D.E. *"Predicting Oxygen Depletion during Grain Storage using Hermetic Bag Technology"*, 3rd All Africa Postharvest Congress and Exhibition (Virtual Event), September 13 to 16, 2021

Ignacio M.C.C.D. and Maier D.E. *"Predicting Oxygen Depletion during Grain Storage using Hermetic Bag Technology"*, 11th International Virtual Conference on Controlled Atmosphere and Fumigation in Stored Products (CAF2020), August 22-27, 2021

Ignacio M.C.C.D. and Maier D.E. *"Characterizing Engineering Properties of Hermetic Storage Bag Technology for Standards Development"*, 11th International Virtual Conference on Controlled Atmosphere and Fumigation in Stored Products (CAF2020), August 22-27, 2021

Ignacio M.C.C.D. and Maier D.E. *"Predicting Oxygen Depletion during Grain Storage using Hermetic Bag Technology"*, ASABE AIM 2021 Virtual and On Demand, July 12-16, 2021

Ignacio M.C.C.D. and Maier D.E. "Understanding the properties of Hermetic Storage Bag to characterize its performance", Graduate Student Research Symposium, Consortium for Innovation in Post-Harvest Loss and Food Waste Reduction, June 3, 2021 **(*2nd Place-Best Presentation)***

Ignacio M.C.C.D. and Maier D.E. *"Predicting Oxygen Depletion during Grain Storage using Hermetic Bag Technology"*, NC-213 Annual Meeting 2021 – Virtual, March 30 – 31, 2021

## Title

Reducing Post-harvest Loss in the Shea Value Chain of Rural Ghana.

## By

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Obeng-Akrofi, G., Graduate Research Associate, Agricultural & Biosystems Engineering
Arriaga, C., Graduate Research Associate, Food Science and Human Nutrition
Brumm, T.J., Associate Professor, Agricultural & Biosystems Engineering
Rosentrater, K.A., Associate Professor, Agricultural & Biosystems Engineering
White, W.S., Associate Professor, Food Science and Human Nutrition
Sonka, S., Associate Graduate Professor, Agricultural and Biosystems Engineering

## Research Updates

Shea tree is a cash crop predominantly grown in the wild of the shea region spanning from Senegal to Ethiopia on the African continent. Shea nuts are harvested from shea trees and are used in the production of shea butter. As of 2010, USAID estimated that the shea industry generates between USD 90 and 200 million per year in sales of shea nuts and shea butter exports. There has been considerable research and information on the socio-economic potential of the shea industry in rural communities where shea nuts are produced, on engineering properties and processing of shea nuts into shea butter, and on the nutritional capabilities of the commodity. However, information regarding the post-harvest handling and preservation of shea nuts has not been given much attention. At the rural level where shea nuts are produced, a substantial amount of shea nuts are lost due to post-harvest handling, making the nutritional and economical utilization of shea nuts a challenge. This research's primary goal was to reduce post-harvest loss in the shea value chain of rural Ghana.

## Outputs

Study 1: Assessment of post-harvest loss of shea nuts in the value chain at a rural production level

Over the summer of 2021, a shea nut postharvest loss assessment survey was carried out in Ullo, a shea growing community in the Upper West Region of Ghana. In all, 300 in-depth interviews were undertaken using a semi-structured questionnaire. The participants interviewed were rural shea women who were involved in the picking and processing of shea fruits to shea butter and storage and marketing of shea nuts. The results of the study found that drying and storage tasks continue to be a bottleneck in the sustainable production of shea nuts in Ullo. It was recommended from the study that the Yieldwise model in reducing food and post-harvest loss has potential to improve the shea nut value chain for improved livelihood in the community.

Study 2: Assessment of the viability of hermetic bag storage of shea nuts to mitigate post-harvest loss and maintain the quality of shea nuts

Hermetic storage bags have proven to be a viable option for the effective storage of grains in sub-Saharan Africa due to their simplicity, low cost, and efficacy. However, little is known on the effectiveness of hermetic storage bags in the storage of shea nuts. In this study, three different storage bags; hermetic bags, jute sacks, and woven polypropylene (PP) bags, were used to store shea nuts with an initial moisture content of 7.3% (w.b.), 28% insect-damaged nuts and 4.5% initial weight loss over a 30-week storage period. Each of the storage treatments consisted of 12 bags of 20 kg shea nuts. Samples were taken from 3 bags at the end of the 6th, 12th, 21st and 30th week of storage. The moisture content of shea nuts was maintained in hermetic bags as a function of ambient temperature

and relative humidity conditions. Nuts varied within 1 percentage point as compared to 3 percentage points for nuts in the jute and PP bags. Insect damage of shea nuts in hermetic bags was contained below 30.0% as compared to 82% and 80% in jute and PP bags, respectively. The percentage of weight loss due to insect damage was maintained at 4.5% in the hermetic bags, 10.1% in the jute sacks and 11.6% in the PP bags. Carbon dioxide concentration in the hermetic bag was below 6%, indicating low microbial activity in the hermetic bag over the storage period. Through this research, hermetic bag technology has been demonstrated to be a viable option for the quality preservation of shea nuts and is recommended for adoption.

Study 3: Assessment of the effect of different storage systems on the nutrient retention of shea butter produced from shea nuts stored in these storage systems

The ultimate form in which shea nuts are utilized is in the form of shea butter. The butter serves as a fat source in diets and serves as a cosmetic and therapeutic product at the rural level. Storing shea nuts differently could potentially affect the nutritional quality (and thus value) of the butter processed from the nuts. Processed shea butter from nuts sampled from the second study (using the respective storage treatments) were analyzed for micronutrients such as vitamin E (tocopherols), vitamin K (phylloquinone) and carotenoids (beta-carotene). Shea nuts samples from the baseline qualitative analysis were processed into shea butter in Ghana and subsequently shipped to Iowa State University for nutritional analyses following government export/import protocols. The presence of vitamin E has been established using GC-MS (Gas Chromatography and Mass Spectrometer detector). The next step will be to use LC-MS (Liquid Chromatography and Mass Spectrometer) to determine the presence (or not) of vitamin K and carotenoids. In addition to contributing new data to the scientific literature, this study will inform on the impact of different storage methods on the nutritional variability of shea butter.

Study 4: Life Cycle Analysis (LCA) and Techno-Economic Assessment (TEA) of a model-based mobile shea nut processing system and a conventional stationary shea nut processing unit

Processing of shea nuts into shea butter involves various unit operations; crushing, roasting, milling, kneading, and boiling. These operations are tediously carried out by women in shea growing communities using manual efforts. The traditional processing method was inefficient, consuming many resources. In pursuit of better production systems, some processors employ machinery to carry out these unit operations at a stationary location. However, shea growing communities are characterized by widely-spread small villages that form a community. The use of a mobile processing unit could be essential in providing timely processing needs in these villages. To measure how viable and appropriate such a mobile system would be at the rural level, LCA and TEA will be applied to make such an assessment. A comparative evaluation will also be made on a conventional stationary processing system. The most viable option will be proposed to be implemented in a rural shea growing community in Ghana.

## Funding Sources

The Rockefeller Foundation (Grant #2018 FOD 004)

Foundation for Food and Agriculture Research (Grant # DFs-18-0000000008)

Iowa Agriculture and Home Economics Experiment Station

## Publications

Peer-Reviewed Journal Articles

Obeng-Akrofi, George, Joseph O. Akowuah, Dirk E. Maier, and Ahmad Addo. 2021. “Techno-Economic Analysis

of a Crossflow Column Dryer for Maize Drying in Ghana." *Agriculture* 11 (6): 568. https://doi.org/10.3390/agriculture11060568.

Asante, Eric Amoah, Joseph Oppong Akowuah, Samuel Appah, and George Obeng-Akrofi. 2021. "Mechanised Threshing of Pod Grains Used as Food and Strategies to Optimise the Technique: A Review Eric." *Journal of Advances in Agriculture* 12: 30–43. https://doi.org/https://doi.org/10.24297/jaa.v12i.9045

Owusu-Sekyere, Ernest, George Obeng-Akrofi, Joseph O. Akowuah, and Dirk Maier. 2021. "Performance Analysis and Drying Kinetics of Maize in an AflaSTOP Dryer." *Open Journal of Applied Sciences* 11 (03): 327–42. https://doi.org/10.4236/ojapps.2021.113024.

Armah, Kwashie A., Joseph O. Akowuah, George Obeng-Akrofi, and Samuel G. McNeill. 2021. "Application of Analytic Hierarchy Process in Selection of an Appropriate Drying Platform for Maize Drying in a Solar Bubble Dryer." *Open Journal of Applied Sciences* 11 (01): 157–75. https://doi.org/10.4236/ojapps.2021.111011.

Oral Presentations

Boateng, H.A., G. Obeng-Akrofi, J.O. Akowuah, and D.E. Maier. Performance Evaluation of a Flatbed Maize Dryer with a Biomass Heat Source. ASABE 2021 Virtual Annual International Conference, July 12 - 16, 2021.

Owusu, G., G. Obeng-Akrofi, J.O. Akowuah, and D.E. Maier. Comparative Assessment of Three Low-Capacity Drying System using Analytical Hierarchy Process. ASABE 2021 Virtual Annual International Conference, July 12 - 16, 2021.

Obeng-Akrofi G., D. E. Maier, W. S. White, A. Bart-Plange, J. O. Akowuah, R. Bartosik and L. Cardoso Evaluation of Hermetic Bag Technology to Preserve Shea Nuts in Rural Ghana. 11th Conference on Controlled Atmospheres and Fumigation in Stored Products (CAF2020), August 22 - 27, 2021.

Obeng-Akrofi G., D. E. Maier, W. S. White, A. Bart-Plange, J. O. Akowuah, R. Bartosik and L. Cardoso Evaluation of Hermetic Bag Technology to Preserve Shea Nuts in Rural Ghana. 3rd All Africa Post-Harvest Congress and Exhibition. Virtual Event. September 13 - 17, 2021.

Poster Presentations

Obeng-Akrofi G., J.O. Akowuah, D.E. Maier and A. Addo. Selection of an Appropriate Biomass Burner for Drying Maize in a Column Dryer Using the Analytic Hierarchy Process (AHP). ASABE 2021 Virtual Annual International Conference, July 12 - 16, 2021.

Obeng-Akrofi G., D. E. Maier, W. S. White, A. Bart-Plange, J. O. Akowuah, R. Bartosik and L. Cardoso Evaluation of Hermetic Bag Technology to Preserve Shea Nuts in Rural Ghana. ASABE 2021 Virtual Annual International Conference, July 12 - 16, 2021.

Obeng-Akrofi G., J.O. Akowuah, D.E. Maier and A. Addo. Selection of an Appropriate Biomass Burner for Drying Maize in a Column Dryer Using the Analytic Hierarchy Process (AHP). 3rd All Africa Post-Harvest Congress and Exhibition. Virtual Event. September 13 - 17, 2021.

Obeng-Akrofi G., D.E. Maier and J.O. Akowuah. Application of the Analytic Hierarchy Process (AHP) in the Selection of a Storage Bag for Possible Adoption in Ullo, a Shea Growing Community in Ghana. 3rd All Africa Post-Harvest Congress and Exhibition. Virtual Event. September 13 - 17, 2021.

## Title

Marketing and Delivery of Quality Grains and BioProcess Coproducts.

## By

Rose, D., University of Nebraska-Lincoln
Bianchini-Huebner, A.
Stratton, J.

## Outputs

For Nebraska-specific objective 1, steam treatments with or without tempering with organic acids was examined for its efficacy at reducing microbial load of hard and soft wheat kernels. For treatments where steam was included, samples were placed into sieves (bed depth 0.5 and 1.0 cm) and then placed in a steam table until the center of the grain bed temperature achieved 80°C or 85°C. For treatments where lactic acid was added, solutions of lactic acid were used for tempering (1.81μL/g of wheat). For both hard and soft wheat, the combination of steam treatment to 85°C with a 1.0 cm grain bed depth and tempering with lactic acid provided the highest reduction in APC and Eb [3.64 log CFU/g (hard, APC), 5.49 log CFU/g (soft, APC), 3.64 log CFU/g (hard, Eb), and 4.39 log CFU/g (soft, Eb)]. When the bed depth and temperature of steaming decreased, so was the efficacy of the steam treatment, showing that microbial reduction would decrease when decreasing the temperature and exposure time to the steam. For both hard and soft wheat, steam treatments resulted in small, but significant changes in starch pasting characteristics, including peak, trough, breakdown, final, and setback viscosity, time to peak viscosity, and pasting temperature. However, the baking quality of cookies (soft wheat) or bread (hard wheat) was not significantly affected by any treatment. Even though the interventions suggested here provided promising application in the milling industry, further research is needed on different wheat classes and the impact of the treatment on sensory characteristics of the end-products.

For Nebraska-specific objective 2, we examined asparagine concentration, as well as the concentration of 15 other grain metabolites, in 19 wheat cultivars and 2 landraces released or introduced between 1870 and 2013 and grown over two crop years using 1H NMR spectral profiling. The mean asparagine concentration varied between 0.47 and 0.93 g/kg. Asparagine and the sum of the measured amino acids showed dramatically different effects by release year; in 2017 there was a significant increase in these compounds across release years while in 2016 there was no trend across release year. Increasing trends ($p < 0.01$) were observed for tryptophan, chlorogenic acid, ferulic acid, vanillic acid, and sum of the measured phenolic acids. The findings from this study showed changes in concentration of grain components over a century of breeding that may have implications for grain quality and human health.

For Nebraska-specific objective 3, we evaluated the effects of fungicide application on cadmium concentration in historical and modern wheat cultivars representing 80 years of plant breeding efforts. Field experiments were conducted over two crop years (2017 and 2018) with eighteen hard winter wheat genotypes released between 1933 and 2013 in the presence or absence of fungicide application. For each growing season, the treatments were arranged in a split-plot design with the fungicide levels (treated and untreated) as the whole plot treatments and the genotypes as split-plot treatments in triplicate. Grain Cd significantly increased over time (0.4 μg kg-1 yr-1, $P < 0.01$) in the absence of fungicide. In contrast, Fe (-35.0 and -44.0 μg kg-1 yr-1, $P < 0.05$) and Zn (-68.0 and -57.0 μg kg-1 yr-1, $P < 0.01$) significantly decreased during the period studied. The results from this study are of great concern, as many mineral elements essential for human nutrition have decreased over time while the toxic heavy metal, Cd, has increased, indicating modern wheats are becoming a better vector of dietary Cd.

## Outcomes/Impacts

We have established steam treatment and lactic acid tempering conditions to reduce microbial contamination in wheat kernels. These treatments have minor effects on the physical properties of the resulting flour, but do not have a significant effect on baking quality. Even though the interventions suggested here provided promising application in the milling industry, further research is needed on different wheat classes and the impact of the treatment on sensory characteristics of the end-products.

Our survey of wheat composition between historical and modern wheat cultivars suggests that more efforts need to be made to ensure safe nutritional quality of modern wheats. Modern wheats tended to have more free amino acids, including asparagine, which may be a risk for acrylamide production. They also had higher Cd concentrations and reduced Fe and Zn.

## Publications

Motta-Romero H, Niyongira F, Boehm J, Rose DJ. 2021. Effects of foliar fungicide on yield, micronutrients, and cadmium in grains from historical and modern hard winter wheat genotypes. PLoS One 16:e0247809.

Poudel R, Bhinderwala F, Morton M, Powers R, Rose DJ. 2021. Metabolic profiling of historical and modern wheat cultivars using proton nuclear magnetic resonance spectroscopy. Scientific Reports 11:3080.

## Title

Evaluating Durum Quality using the Solvent Retention Capacity Test.

## By

Manthey, F. A., North Dakota State University, Fargo

## Outcomes/Impacts:

*Impact*: Solvent Retention Capacity test is a simple test that provides an opportunity to rapidly evaluate semolina/flour for its dough and pasta quality. Dough properties provide important information relative to the manufacturing of pasta. Solvent Retention Capacity test could provide useful information to the durum breeder when selecting genotypes to be used in cultivar development and to the pasta processor when selecting durum flour/semolina to be used in manufacturing pasta products.

*Summary statistics and discussion of results*: Solvent retention values for solutions of sucrose and lactic acid related well with gluten index (protein quality), mixogram score (dough quality), and cooked weight and cooked firmness of spaghetti. Neither the mixogram score nor any of the solvents correlated with cooking loss of spaghetti. Mixogram score and retention capacities of sucrose solution and lactic acid solution were negatively correlated with cooked weight. Conversely, cooked firmness and gluten index were positively correlated to mixogram score and retention of sucrose solution and lactic acid solution. Data indicate that the Solvent Retention Capacity for sucrose and lactic acid could be used to replace the mixogram score as a test to predict dough and spaghetti cooking quality.

*Key outcomes or other accomplishments realized:* This project provided training in durum wheat quality evaluation for one MS student.

## Title

Evaluating Oat Varieties and Isolation Processing on Functional Properties of Oat Protein.

## By

Rao, J., North Dakota State University, Fargo

## Outcomes/Impacts

*Impact*: Oat is one of the most nutritional cereal grains owning to its relatively high amounts of oil and protein, as well as bioactive dietary fiber β-glucan. Depending on the varieties, oat grains contain 12−20% protein content, 5–10% oil, and 3–14% crude fiber. Because of its high protein content and nutritional quality (Gorissen et al., 2018), oat grains can be considered as a promising plant resource for obtaining plant-based protein. Nevertheless, very limited information is available on how varieties and processing conditions influence the structural, functionality, and aromatic profiles of oat proteins. This research provides useful information to the oat breeder when selecting genotypes to be used in cultivar development for protein application and to the plant protein ingredient company when selecting oat to be used in oat protein isolation.

*Summary statistics and discussion of results*: Data indicated that oat proteins from defatted flour (DF) exhibited significantly higher protein purities (>86.93%) and extremely lower lipids content (< 0.41%) in general. Protein extraction yield and protein recovery yield for oat protein from DF was also low for most of the varieties except for naked oat variety ND040341 which were quite close to that from NDF. Defatting treatment also impacted the protein composition and structural properties by facilitating the recovery of 7S globulins fraction into oat proteins, and elevating β-sheet proportion in the extracted oat protein, respectively. Such unique structure properties of oat protein from ND endowed a better thermal stability and solubility, a greater foaming capacity, emulsion capacity and stability.

*Key outcomes or other accomplishments realized:* This project provided training in oat protein quality evaluation for one Ph.D. student.

## Publications

Jianxiong Yue, Zhenbao Zhu, Jianhua Yi, Hui Li, Bingcan Chen, Jiajia Rao* (2021). Impact of defatting treatment and oat varieties on structural, functional properties, and aromatic profile of oat protein. Food hydrocolloids 112, 106368.

Jianxiong Yue, Zhenbao Zhu, Jianhua Yi, Yang Lan, Bingcan Chen, Jiajia Rao * (2021). Structure and functionality of oat protein extracted by choline chloride–dihydric alcohol deep eutectic solvent and its water binary mixtures. Food hydrocolloids 112, 106330.

## Title

Monitoring Stored Grain to Manage Quality.

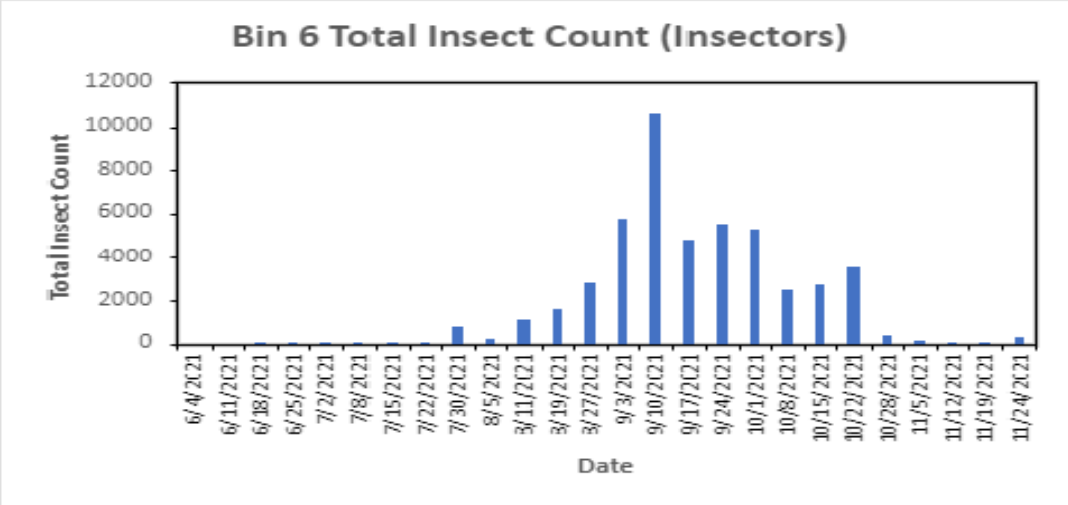
## By

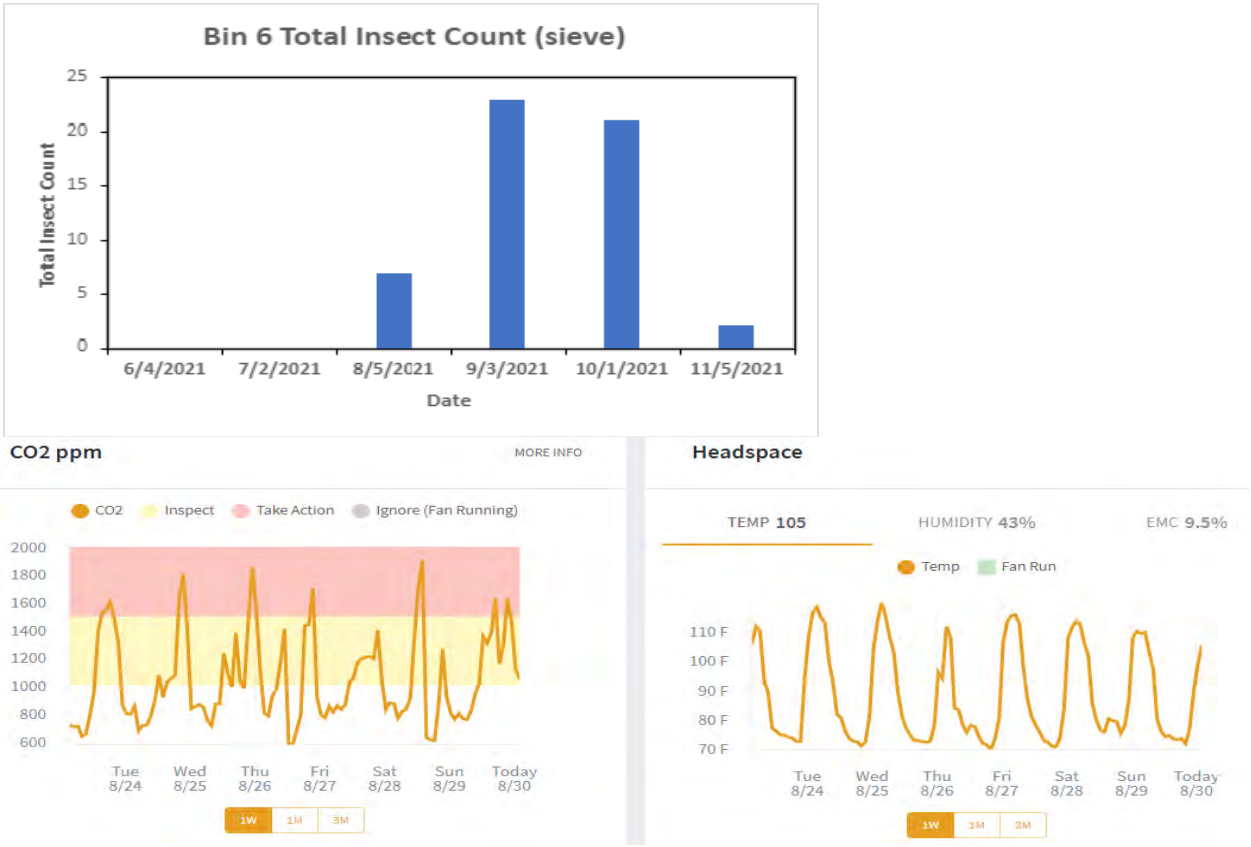
Olenloa, A., Visiting Graduate Research Scholar, Agricultural & Biological Engineering, Purdue University
Ileleji, K.E., Professor & Extension Engineer

## Outputs

Conditions of stored grain year-round is vital to its quality and economic value. While the monitoring of stored grain to know whether it is in good condition is not new, anecdotal evidence suggests that less than 10% of stored grain on U.S. farms are actively monitored for one or several parameters. The lack of stored grain monitoring has been partly due to the lack of availability of technological options coupled with beneficial user experience by farmers. The use of stored grain monitoring systems in grain elevators are higher, but the user experiences still need to be improved. A lot of these systems measure temperature, moisture content, relative humidity, and carbon dioxide of the stored grain ecosystem, and present data on user-friendly dashboards. However, there is still a lack of understanding of what these measured parameters indicate – *symptoms of grain condition or quality loss of grain*. They nevertheless, still provide some measure of the grain condition, but pose a challenge in their use to make actionable management decisions, especially when the farmer or operations manager is trying to understand how critical a problem might be or relate the measured data to loss in grain value.

About 350 bu of newly harvested corn was monitored for about a year (November 2020-November 2021) in eight 500-bu capacity cylindrical steel pilot bins in West Lafayette, Indiana, USA. Sensors from two technological systems were used to log hourly data of stored grain for headspace temperature, moisture content, relative humidity, and $CO_2$. Insect probe traps (Insectors, OPI Systems, Calgary, Canada) and flight traps (Insect Limited, Westfield, Indiana, USA) were installed to measure insect activity during the warm period (spring to fall). Grain was probed biweekly to sample for insects, determine grain composition and measure susceptibility to spoilage.






Insect activity in the insect probe traps began being recorded from July 2021, when temperatures in the grain bin headspace peaked at or slightly above 110°F. During this time, $CO_2$ levels recorded in the headspace ranged between 600 to 1800 ppm. The High $CO_2$ band when inspection or action is required ranged from 1000 to 1800ppm. Insect count in probe traps increased steadily through to September and began to decline afterwards. Of interest is the correlation between insect count trapped in-situ in the grain mass and insect count from screened grain samples collected biweekly from the bins. The latter was a lot higher and was observed a lot sooner than the former. Additionally, probed samples were analyzed for their susceptibility to spoilage using the Solvita Kit (Woodend Lab, Mt. Vernon, ME). Later, samples would be sent to a license grain grader to determine corn grade over time. When fully analyzed, the results would provide a good understanding of the seasonal patterns of physical and biological conditions of stored corn during the spring to fall season.

## Outcomes/Impacts

The parameters measured provide a good understanding of seasonal patterns of biological activity in stored corn, especially during the spring to fall warm conditions when stored grain is more susceptible to spoilage. Our ultimate goal is to better understand how these parameters correlate to stored grain quality and economic value, and how they can be used for actionable decision making by farmers and stored grain managers.

## Funding Sources

Hatch

## Contact

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## Title

Enhancing Utilization of Hulled Wheats: Quality and Composition.

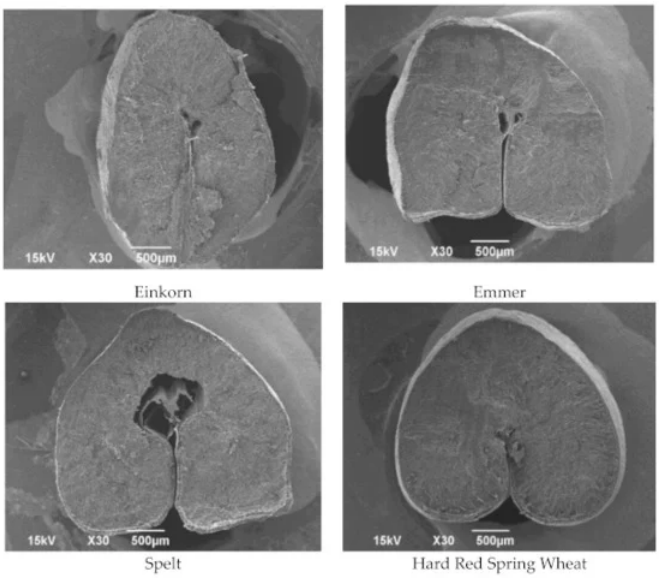
## By

Simsek, S., Purdue University

## Outputs

The increasing interest of consumers shown in natural and organic products has led to the reintroduction of hulled wheat. Underutilized hulled wheat can serve as a valuable raw material to produce a variety of food products. Hulled wheat products such as bulgur, grunken, sourdough bread, non-durum pasta, and breakfast cereals will expand the hulled wheat market. However, research and breeding efforts are still needed to assess the genetic diversity of hulled wheat for their proposed health benefits.

Hulled wheat species are often used as whole grains in processing and have been attracting attention in the last 20 years in the food industry. Therefore, whole wheat flour of hulled wheat can be used in the food industry for value addition. This study was conducted to evaluate the kernel quality and chemical composition of the whole grain flour of hulled wheats as a preliminary approach to use these species for value addition. The experimental design was separate, randomized complete block designs for einkorn, emmer, and spelt, with four field replicates. The results showed significant differences ($p < 0.05$) in kernel quality traits, such as test weight, 1000 kernel weight, and kernel hardness, compared to hard red spring wheat. The results of the chemical composition revealed that hulled wheats were characterized by significantly lower ($p < 0.05$) protein and higher ($p < 0.05$) crude fat contents compared to whole wheat flour of hard red spring wheat. Among hulled wheats, total dietary fiber content was highest in emmer, followed by einkorn and spelt. In conclusion, the whole wheat flour of einkorn, emmer, and spelt used in this study differ from hard red spring wheat in their kernel quality and chemical composition.




Significant differences ($p < 0.05$) were observed in the test weight and grain hardness of hulled wheat, which could be explained by the shape of the kernel and the microstructure of the endosperm. Einkorn was identified as extra soft-textured kernels; in contrast, emmer was a hard-type wheat, similar to hard red spring wheat. Both medium-soft and hard genotypes were observed in spelt. The chemical composition of hulled wheats revealed they have significantly higher ($p < 0.05$) crude fat contents. Therefore, further studies should investigate the stability of lipid components during storage and while in food products. In addition, aspects that need to be addressed in any such comparative study should include genotype and location interactions, and other required phenotypic assessments, through multiple-year and multiple-location trials.

## Outcomes/Impacts

This project has initiated the development of a compressive assessment of hulled wheat quality and composition in comparison to hard red spring wheat. Therefore, the information collected in this project can be leveraged to increase knowledge and utilization of hulled wheat species. In addition, a better understanding of the nutritional quality of hulled wheats was determined, and this will aid in the development of value-added products from hulled wheats. Overall, the information from this work may lead to increased market share for hulled wheats through a better understanding of quality, composition, and functionality. Thus, aiding the agriculture and food industries in improved and increased utilization of these grains.

## Publications

Kulathunga, J., Reuhs, B. L., & Simsek, S. (2020). A review: Novel trends in hulled wheat processing for value addition. Trends in Food Science & Technology.

Dona, JM., Simsek, S. (2020). Baking and nutritional quality of bread made from whole-grain hulled wheat. Cereals and Grains Association Annual Meeting. Online

Kulathunga, J., Reuhs, B. L., Zwinger, S., & Simsek, S. (2021). Comparative Study on Kernel Quality and Chemical Composition of Ancient and Modern Wheat Species: Einkorn, Emmer, Spelt and Hard Red Spring Wheat. Foods, 10(4), 761.

## Contact

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## Title

Relationships between Sorghum Grain Composition and Chemistry and Functionality of Sorghum Proteins.

## By

Bean, Scott, R., CGAHR, USDA-ARS, Manhattan, KS

## Outputs

Factors influencing sorghum grain composition including nitrogen and sulfur fertilization were investigated.

## Outcomes/Impacts

Sorghum is a drought and heat tolerant crop important to arid areas of the central U.S. and an important crop for food and feed around the world. Sorghum's tolerance to abiotic stresses and resilience plays an important role in food security. While sorghum grain has important nutritional properties, there are grain quality attributes and nutritional factors that can be improved to enhance the value and utilization of sorghum. This research addressed those issues by developing methodology to determine sorghum grain composition by FTIR; testing the use of NIR and LIBS for determining the composition of mixtures of corn and sorghum flour; providing grain composition data for sorghum germplasm releases; and developing robust NIR curves to predict starch content and composition in sorghum grain.

## Publications

Lin, H., Bean, S.R., Tilley, M., Peiris, K.H.S., and Brabec, D. 2021. Qualitative and quantitative analysis of sorghum grain composition including protein and tannins using ATR-FTIR spectroscopy. Food Analytical Methods. 14:268-279.

Weerasooriya, D., Bandara, A., Dowell, F., Peiris, S., Bean, S.R, Perumal, R., Adee, E., and Tesso, T. 2021. Performance of grain sorghum hybrids resistant to acetolactate synthase (ALS) and acetyl coenzyme-A carboxylase (ACCase) inhibitor herbicides. Crop Science. 61:896-916

Akin, P.A., Sezer, B., Bean, S.R., Peiris, K., Tilley, M., Apaydin, H., and Boyaci, I.H. 2021. Discrimination of corn and sorghum flour mixtures using laser induced breakdown spectroscopy. J. Sci. Food Agric. 101: 076-1084.

Taghvaei1, M., Smith, B., Yazar1, G., Bean, S., Tilley, M., Ioerger, B. 2021. Identification of gluten-like proteins in selected pod bearing leguminous tree seeds. PLoS ONE 16(4): e0249427. https://doi.org/10.1371/journal.pone.0249427.

*Bean, S.R, Akin, P.A., Aramouni, F.M. 2021. Zein functionality in viscoelastic dough for baked food products. J. Cereal Sci. 100:103270.

Perumal, R., Tesso, T.T., Morris, G.P., Jagadish, S.V.K., Little, C.R., Bean, S.R., Yu, J., Prasad, P.V.V., and Tuinstra, M.R. 2021. Registration of the sorghum nested association mapping (NAM) population in RTx430 background. J. Plant Registrations 15:295-402.

Yoganandan, M., Bean, S.R., Miller-Regan, R., Dogan, H., Pulivarth, M. K., and Siliveru, K. 2021. Effect of tempering conditions on white sorghum milling, flour, and bread properties. Foods. 10:1947.

Cao, Z, Li, N., Qi, G., Sun, X.S., Bean, S.R., Tilley, M., Aramouni, F.M., and Wang, D. 2021. Optimization of camelina gum isolation from bran and protein extraction using decortication. Journal of Agriculture and Food Research. 6:100223

Peiris, K.H.S., Wu, X., Bean, S.R., Perez-Fajardo, M., Hayes, C., Yerka, M.K., Jagadish, S.V., Ostmeyer, T., Aramouni, F.M., Tesso, T., Perumal, R., Rooney, W.L., Kent, M.A., and Bean, B. 2021. Near infrared spectroscopic evaluation of starch properties of diverse sorghum populations. Processes. 9:1942. https://doi.org/10.3390/pr9111942

**NC-213 (The U.S. Quality Grains Research Consortium)**

**Objective 2**

To improve management and operational systems to increase efficiency, retain quality, enhance value, and preserve food safety in the farm-to-user supply chain.

## Title

Processing and Post-harvest Systems Engineering for Grains to Maintain Quality and Prevent Mycotoxin Contamination.

## By

Atungulu, G.G., University of Arkansas, Division of Agriculture

## Outputs

Issues:

Drying
In-bin rice drying, chilling and storage: experiment, mathematical modeling, simulation, validation and assessment of operations which use new grain management tools including temperature, moisture and CO2 sensors.

Characterizing the glass transition temperatures of contemporary rice cultivars

Characterization of fissures created during drying using an x-ray system and impacts of the drying on seed germination and overall health.

Application of dielectric heating in rice drying, instantization and pasteurization.

Milling

Standardization of methods which use different milling equipment to perform laboratory milling yield assessment of contemporary rice cultivars.

Assessment of new nondestructive methods to measure rice chalk content based on rough rice dielectric properties.

Quantifying physicochemical and functional characteristics of a wide range of rice cultivars.

Comparing the values of gelatinization temperature obtained by RVA and DSC methods.

Storage and safety

Kinetics of aflatoxin formation on various fractions of rice and its flour.

Development of methods which use dielectric heat treatments to control insect pests on rough, brown and milled rice.

Response:

In collaboration with grain producers, processors and allied scientist and engineers, our researches, through lab- and field-based experiments as well simulations and modeling of the EMC-based in-bin drying, sought to answer primary and practical questions that are needed to successfully implement new equilibrium moisture content based in-bin drying systems in Arkansas. These systems use sensors on cables or CO2 sensors to monitor grain quality and automate the drying and storage process. These questions included (1) what is the rate of grain “quality”

reduction and mycotoxin development under various drying and storage scenarios; (2) with respect to stored product "quality", what is the upper moisture content limit for rice placed into these systems at various geographic locations; and (3) what energy savings could be realized with these new in-bin drying/storage systems? We developed a computer simulation platform capable of predicting natural air in-bin drying of rice using multiple fan running strategies practical for Arkansas conditions. The models used in the simulations were validated using field experiments and in-bin sensors built using newly generated EMC-based mathematical relationships. Charts were generated to document "suitable" in-bin rice drying and storage regimes based on the rice harvest moisture content, rice harvest date, drying air flowrate, and fan control strategy. Advanced engineering, management and optimization of on-farm, in-bin drying, chilling, storage and aeration processes for the high quality and safety of grains. In addition to the forgoing responses the following have been undertaken: develop novel techniques to enhance drying rates while maintaining grain quality, engineer methods for detection, decontamination, and detoxification of harmful-grain molds and mycotoxins, and explore grain and grain processing by-product value addition and utilization.

## Outcome/Impacts

Rice growers managing some 15 million bushels of rice stored in on-farm bins in Arkansas, Louisiana, and Mississippi use newly generated guidelines for rice harvest moisture content and management strategies to completely eliminate discoloration during in-bin rice drying and storage. We have seen a shift from traditional practices to adopt new guidelines that recommend harvest moisture content of 18-19% thereby preserving rice quality and milling yields. Sensors built using newly generated mathematical relationships for predicting rice EMC have been adopted by nearly 100 growers in Arkansas and elsewhere to help automate monitoring of rice condition inside grain bins and controlling of drying fans. The research had provided opportunity for training the next generation of grain processing and post-harvest system engineers; these include six doctoral and one masters students who completed their degree under my supervision as their dissertation or thesis director. In addition, we have trained two undergraduate honors students and currently serve on four doctoral students' committees.

## Publications

Bruce RM, Atungulu GG*, Sadaka S, Smith D. 2021. Impact of specific energy input of a 915 MHz microwave dryer on quality, functional, and physicochemical properties of different rice cultivars. Cereal Chemistry, 98(3), 557-570. DOI: 10.1002/cche.10398

Wilson SA, Mohammadi Shad Z, Oduola AA, Zhou Z, Jiang H, Carbonero F, Atungulu GG*. 2021. Decontamination of Mycotoxigenic Fungi on Shelled Corn Using Selective Infrared Heating Technique. Cereal Chemistry, 98(1), 31-43. https://doi.org/10.1002/cche.10394

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Shafiekhani S, Rocha M, Finberg E, Shiflett M, Atungulu GG*. 2021. Modeling heat and mass transfer of long-grain hybrid rice in a chilled environment. Applied Engineering in Agriculture. In press. Doi: 10.13031/aea.14440.

Hampton RM, Atungulu GG, Rolland V, Wilson S, McKay* T. 2021. Effects of infrared radiation on germination of long grain rice. Applied Engineering in Agriculture. Accepted

Sadaka S*, Atungulu GG, Kelley J. 2021. Corn drying, storage, and aflatoxin levels. FSA1100. https://www.uaex.uada.edu/publications/pdf/FSA1100.pdf (Refereed Extension Factsheet)

Title

Risk Assessment for the Food Safety Concerns of Mycotoxins in the Pacific Northwest under Climate Variability.

## By

Ryu, D. University of Idaho

## Outputs

Ochratoxin A (OTA) is a possible human carcinogen found in a wide range of foods and agricultural commodities worldwide particularly in cereal grains including oats, wheat and barley. This potent nephrotoxin is of concern because of its thermal stability under most conditions used during food processing and high incidence and concentration in oat-based baby foods. Hence, means to achieve greater reduction of OTA during food processing and possible its potential impact on food safety were investigated. In addition, formation of known and unknown degradation products that may affect toxicity of OTA and its derivatives were measured. In an aqueous model system in the absence of food matrix, added fructose facilitated reduction of OTA during thermal processing. The major degradation product of OTA during thermal processing in the absence or presence of sugar was OTA isomer (known to be toxic) or OTα-amide (non-toxic OTA analog), respectively. In an attempt to elucidate the mechanism of toxicity, OTA has shown to induce oxidative stress in HepG2 cells by impairing the gene expression of antioxidant enzymes.

## Outcomes/Impacts

Summary: The Multistate program has provided food industry and general public with a potential measure to ensure food safety by reducing OTA and its toxicity.

Situation: Ochratoxin A (OTA) is a possible human carcinogen found in a wide range of foods and agricultural commodities worldwide particularly in cereal grains including oats, wheat and barley. This potent nephrotoxin is of concern because of its thermal stability under most conditions used during food processing and high incidence and concentration in oat-based baby foods.

Response: Means to achieve greater reduction of OTA during food processing and possible its potential impact on food safety were investigated. In addition, formation of known and unknown degradation products that may affect toxicity of OTA and its derivatives were measured. In an aqueous model system in the absence of food matrix, added fructose facilitated reduction of OTA during thermal processing. The major degradation product of OTA during thermal processing in the absence or presence of sugar was OTA isomer (known to be toxic) or OTα-amide (non-toxic OTA analog), respectively. In an attempt to elucidate the mechanism of toxicity, OTA has shown to induce oxidative stress in HepG2 cells by impairing the gene expression of antioxidant enzymes.

## Impacts

It was discovered that sugars, common ingredients in processed foods, may affect the fate of OTA. Among all sugars tested, addition of fructose resulted in the greatest reduction of OTA with highest amount of non-toxic degradation product suggesting most effective reduction in its toxicity.

While the kidney has been known to be a major target organ, OTA showed a significant toxicity in both liver and kidney via oxidative stress. Hence it is recommended to investigate the possible impact of antioxidants in the diet in reducing or counteracting OTA mediated toxicity.

The effect of a thermal food processing on the fate of OTA was dependent on the addition of sugars as common ingredients. Among all sugars tested, addition of fructose resulted in the greatest reduction of OTA with highest amount of non-toxic degradation product suggesting most effective reduction in its toxicity.

The Multistate program has provided food industry and general public with a potential measure to ensure food safety by reducing OTA and its toxicity.

## Publications

García-Pérez, E., D. Ryu, H.Y. Kim, H. Kim, H.J. Lee. 2021. Human proximal tubule epithelial cells (HK-2) as a sensitive *in vitro* system for ochratoxin a induced oxidative stress. *Toxins* 2021, 13(11):787 https://doi.org/10.3390/toxins13110787

García-Pérez, E., D. Ryu, C. Lee, H.J. Lee. 2021. Ochratoxin A induces oxidative stress in HepG2 cells by impairing the gene expression of antioxidant enzymes. *Toxins* 2021, 13(4):271. https://doi.org/10.3390/toxins13040271.

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Gu, K, D. Ryu, and H.J. Lee. 2021. Ochratoxin A and its reaction products affected by sugars during heat processing. *Food Chem.*348:129038. https://doi.org/10.1016/j.foodchem.2021.129038

## Funding Sources

Ryu, D., O. Balemba, H.J. Lee. [3/1/19 – 2/28/23] $324,578. Protective Effect of Antioxidants against Ochratoxin A in Infant Cereals. Agriculture and Food Research Initiative, National Institute of Food and Agriculture, USDA.

## Awarded Grants and Contracts

Lee, H.J., D, Ryu, J. Ball, and S. Smith. [10/1/21 – 9/30/24] $544,158. Collaborative Food Safety Education and Training for the Deaf and Hard of Hearing Farmers in the Pacific Northwest. Food Safety Outreach Program (FSOP), National Institute of Food and Agriculture, USDA.

Achour, A, H. Lee, and D. Ryu [5/1/2021 – 4/30/2024] $260,000. Detect Sources of Patulin Contaminations in Processed Apple Products. Washington Tree Fruit Research Commission.

## Title

Measurement of Soybean Respiration Rates at Elevated Moisture and Temperature Conditions.

## By

Rausch, K.D., University of Illinois at Urbana-Champaign

Gates, R.S., Iowa State University

Danao, M.-G., University of Nebraska-Lincoln

## Outputs

Time to reach 0.5% dry matter loss (DML) is the estimated maximum allowable storage time (MAST) for shelled corn and has been suggested for use with other grains. Respiration studies have reported various estimates of this threshold depending on the type of grain respiration measurement system (GRMS) and storage conditions tested. The objectives of recently published study were (1) to design and evaluate two systems in which oxygen needed for respiration was limited in a static system (SGRMS) or continuously supplied in a dynamic system (DGRMS) during storage and (2) to compare effects of GRMS on DML rates ($v_{DML}$) for 18% moisture content soybeans stored at 30°C for 20 d. SGRMS and DGRMS units were used to conduct respiration tests. Respired $CO_2$ was measured over time and used to calculate the specific mass of respired $CO_2$ and subsequent DML (%) using stoichiometric ratios from the respiration chemical reaction. DML rates, $v_{DML}$ (% per day), were estimated by least squares linear regression of DML and time data. Means of $v_{DML}$ were 0.0157% per day and 0.0189% per day for SGRMS and DGRMS, respectively. The mean $v_{DML}$ from DGRMS was 1.2 times greater than mean vDML from SGRMS but not statistically different. However, the coefficient of variation was 8 times greater for DGRMS than for SGRMS. More studies with a wider range of storage conditions should be conducted for development of a relational factor between static and dynamic systems prior to using data from respiration of soybeans in the literature to estimate MAST.

The objectives of a second study were to observe effects of 0 to 16% (w/w) splits content of soybeans stored at 35°C and 18% moisture content (wb) on $v_{DML}$ and to determine a splits multiplier ($M_S$) for soybeans stored at these conditions, similar to the damage multiplier ($M_D$) used in ASABE Standard D535 for shelled corn. Effects of percentage by weight splits on $M_S$ and safe storage time were expected to be greater than $M_D$ for corn because soybeans are prone to cracking and splitting, lipid oxidation and protein degradation, all of which lead to dry matter and quality losses. Results indicated that $v_{DML}$ increased with increasing splits content, and mean $v_{DML}$ was 1.5 times greater for samples with 16% splits than for samples with 4% splits. $M_S$ for soybeans was linearly correlated with splits content, decreasing from 1.0 to 0.60 for 0 to 16% splits, respectively. Soybeans appeared to be more sensitive to splits content than corn was to presence of damaged kernels. In Standard D535, $M_D$ for corn only decreased from 1.0 to 0.8 when percent (w/w) damaged kernel content increased from 30 to 40%. It should be noted that damage to soybeans was defined differently from damage to corn. This research is useful in defining $M_S$ for 18% moisture content soybeans stored at 35°C using an SGRMS. The published procedures may be used to more formally define a soybean $M_S$ that covers a wider range of moisture contents, storage conditions and possibly an $M_D$ based on other factors included in the USDA definitions of damaged soybean kernels.

## Outcomes/Impacts

An important impact of this work was to provide an educational opportunity for three Masters students: Ana Gatsakos, Mariane Latanze and Loren Steinman. Gatsakos published two peer reviewed papers from her research work in 2021 (conducted under the advisement of Grace Danao, Richard Gates and Kent Rausch). Latanze (co-advised with Gates) graduated in 2021 and a manuscript is currently in review. Steinman is completing his thesis and is expected to graduate in 2022. It is anticipated that eventually four peer reviewed publications will result from this work on soybean respiration.

Significant losses occur in low latitude regions where soybeans are stored after harvest. Drying and storage facilities are often less than ideal, resulting in dry matter loss and quality degradation. A dynamic grain respiration system was used to measure the respiration rates of soybeans at temperatures and humidity levels typical for storage in low latitude regions. These data were compared to previous research on soybean and corn respiration data.

This research contributes important data to fill gaps in the body of knowledge for soybean storage. Many soybean storage practices are based on the data regarding corn respiration and assumptions from work done on corn from the 1960s through 1980s.

The focus of the work reported here is for soybean storage conditions that would be experienced in the commercial supply chain in low latitude regions such as Brazil and India. These regions have extended high temperature and humidity conditions without cool or cold seasons, in contrast with North America where cold conditions follow harvest of soybeans.

## Publications

Gatsakos, A.B., Scatolini, T.B., Danao, M.-G.C., Gates, R.S. and Rausch, K.D. 2021. Effects of splits content on dry matter loss rates of soybeans measured using a static grain respiration measurement system. Trans. ASABE 64(4):1365-1372.

Gatsakos, A.B., Trevisan, L.R., Sood, K., Rausch, K.D., Danao, M.-G.C. and Gates, R.S. 2021. Comparison of dry matter loss rates from static and dynamic grain respiration measurement systems for soybeans at 18% moisture content and 30°C. Trans. ASABE 64(3):893-903 (in press) https://doi.org/10.13031/trans. 14161.

Latanze, M.P. 2021. Dry matter loss and lipid oxidation evaluation of soybeans during storage at elevated moisture content and temperature. MS thesis, University of Illinois at Urbana-Champaign.

## Funding Sources

This work was supported in part by the ADM Institute for the Prevention of Postharvest Loss at the University of Illinois and the Agência USP de Inovaçao at the University of São Paulo Brazil.

## Title

Distribution of Mycotoxins in Single Corn Kernels and Reflectance Spectroscopy to Identify those Contaminated Kernels for Rapid Testing and Remediation Sorting.

## By

Stasiewicz, M.J., University of Illinois at Urbana-Champaign

## Outputs

To briefly summarize our distribution work, an abstract for a paper that was submitted for review during the 2021 calendar year is as follows:

Aflatoxin and fumonisin contamination distribution in corn is non-homogeneous. Therefore, bulk sample testing may not accurately represent the levels of contamination. Single kernel analysis could provide a solution to these problems and lead to remediation strategies such as sorting. Our study uses extensive single kernel aflatoxin (AF) and fumonisin (FM) measurements to (i) demonstrate skewness, calculate weighted sums of toxin contamination for a sample, and compare those values to bulk measurements, and (ii) improve single kernel classification algorithm performance. Corn kernels with natural contamination of aflatoxin and fumonisin (n = 864, from 9 bulk samples) were scanned individually twice for reflectance between the ultraviolet–visible–near infrared spectrum (304 nm–1086 nm), then ground and measured for aflatoxin and fumonisin using ELISA. Single kernel contamination distribution was non-homogeneous with 1.0% (n = 7) of kernels with ≥20 ppb aflatoxin (range 0 - ppb), and 5.0% (n = 45) kernels with ≥2 ppm fumonisin (range 0 - ppm). A single kernel weighted sum was calculated and compared to bulk measurements. Average difference in mycotoxin levels (AF = 0.0 log(ppb), FM = 0.0 log(ppm), weighted sum – measured bulk levels) calculated no systematic bias between the two methods, though with considerable range of −1.4 to 0.7 log(ppb) for AF and −0.6 to 0.8 log(ppm) for FM. Algorithms were trained on 70% of the kernels to classify aflatoxin (ppb) and fumonisin (ppm), while the remaining 30% of kernels were used for testing. For aflatoxin, the best performing algorithm was stochastic gradient boosting model with an accuracy of 0.83 (Sensitivity (Sn) = 0.75, Specificity (Sp) = 0.83), for both training and testing set. For fumonisin, the penalized discriminant analysis outperformed the rest of the algorithms, with a training accuracy of 0.89 (Sn = 0.87, Sp = 0.88), and testing accuracy of 0.86 (Sn = 0.78, Sp = 0.87). The present study improves the foundations for single kernel classification of aflatoxin and fumonisin in corn, and can be applied to high throughput screening. This study demonstrates the heterogeneous distribution of aflatoxin and fumonisin contamination at single kernel level, comparing bulk levels calculated from those data to traditional bulk tests, and utilizing a UV–Vis–NIR spectroscopy system to classify single corn kernels by aflatoxin and fumonisin level.

## Outcomes/Impacts

A major impact of this work in the last year was a further the education of a PhD student Ruben Chavez. He has completed significant additional work on single kernel analysis of Texas corn. As detailed above.

Another major impact is our publication on sample pooling for mycotoxin detection. We feel that as the number of samples necessary to monitor for mycotoxins in grains increases, these pooling methods may be able to significantly reduce analytical costs for labs that are legally able to use these non-standard analytical approaches. All simulation and data analysis code for this paper, as well as the primary data for validation, can be found at https://github.com/ericxbcheng/Pooling.

## Publications

Chavez, R. A., X. Cheng, T. J. Herrman, and M. J. Stasiewicz. 2022. Single kernel aflatoxin and fumonisin contamination distribution and spectral classification in commercial corn. Food Control. 131(2022)108393. https://doi.org/10.1016/j.foodcont.2021.108393.

X. Cheng and M. J. Stasiewicz. 2021. Evaluation of the impact of skewness, clustering, and probe sampling plan on aflatoxin detection in corn. Risk Analysis. 41(11)2065-2080. https://doi.org/10.1111/risa.13721.

## Funding Sources

This work was supported by the International Life Sciences Institute (ILSI) North America Food Microbiology Committee. ILSI North America is a public, nonprofit science foundation that provides a forum to advance understanding of scientific issues related to the nutritional quality and safety of the food supply. ILSI North America receives support primarily from its industry membership. ILSI North America had no role in the design, analysis, interpretation, or presentation of the data and results.

Other work was supported by the ADM Institute for the Prevention of Postharvest Loss, Postharvest Loss Prevention Graduate Assistantship to RAC (https://postharvestinstitute.illinois.edu/), the Lo Fellowship through the Illinois College of Agriculture, Consumer, and Environmental Sciences to XC (https://fshn.illinois.edu/), and USDA Cooperative State Research, Education, and Extension Service Hatch Project ILLU-698-903 to MJS (https://nifa.usda.gov/grants). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

## Awarded Grants and Contracts

M.J. Stasiewicz (PI). Testing for Enterococcus faceium reduction during corn wet milling dry product production. Corn Refiners Association. $39,297. 2022.

*Upcoming work that is related to this project

## Title

A Risk Management and Cost Estimate Modeling Approach for Effective Segregation of G.M. and non-G.M. Grain in Feed Supply Chain.

## By

Bowers, E.L., Adjunct Assistant Professor, Iowa State University
Hurburgh, C.R., Professor
Mosher, G.A., Associate Professor
Gupta, P., A former Graduate Research Assistant
Pizarro, M., Graduate Research Assistant
Sharma, R., A former Graduate Research Assistant

## Outputs

Adventitious presence (AP), the unintentional or accidental presence of genetically modified (GM) grain within grain lots intended to be non-GM, is a concern for supply chains that wish to produce non-GM animal feed. Management of AP is necessary at every stage to maintain its minimum level in the non-GM feed. A Failure Mode and Effects Analysis (FMEA) was applied to assess the risk of AP in the non-GM feed supply chains for poultry and swine. Over 150 sources of AP from planting to finished feed were identified and evaluated, with assigned probabilities and severity levels used to determine a risk score. Risk scores were compounded across the chain (which included both the grain used directly to feed and the grain to intermediate processed product to feed options) through statistical simulation to predict the likely mean, high, and low contribution of each source.

Traceability is an important factor in supply chains of all kinds, and for a variety of reasons. A major impediment to traceability across a supply chain is inconsistency of terminology and lot definitions, especially for materials handled in bulk. A set of protocols, processes and templates was created specifically for bulk systems, covering the same operations as analyzed for the non-GM feed study. For each general operation, Critical Traceability Events and supporting Key Data Elements were defined.

Cost is an important element in non-GM isolation and segregation. Costs were estimated using Monte Carlo simulation. The analysis has been focused on costs per bushel for corn and soybeans on the farm and at the grain elevator. Costs at the feed mill were measured by animal species feed by ton (swine, broiler, layer, beef, and swine). The analysis measured costs of segregating non-GM feed ingredients and non-GM feed.

## Outcomes/Impacts

Consumer interest in animal products fed non-GM ingredients potentially places hardship on feed supply chains that are primarily configured for undifferentiated bulk handing of the large percentage of feed ingredients (primarily corn and soy based ingredients) that are GM. The impact of this segment of the study is to identify actions that will create AP over acceptable limits, and therefore that should be prioritized in supply chain design.

The traceability system and its standardized descriptions was adapted to a case study of specialty wheat tracked from planting through milling to flour delivery at a food processor. Results are ongoing. Multimillion dollar impacts are possible for the milling company, through the marketing of a very high value specialty wheat in commodity based supply chain with purity maintained, and avoiding the traditional high costs associated with bulk specialty grains. Going forward, numerous tracking problems, such as food safety and environmental/climate impacts, can be documented more efficiently to meet customer specifications or regulations.

Interpretations on the costs of segregation are pending. However, Gupta's dissertation suggests that that segregation costs could be significant, especially in years where prices for non-GM mitigate the additional costs of segregated production and handling. In years where the differences between conventional and non-GM feed and feed ingredients are less, the risk will be higher for producers and handlers. The project also confirmed other research that has stated smaller tolerance levels are more expensive and have higher risk of failure throughout the supply chain.

## Publications

Sharma, R, C. R. Hurburgh, and G. A. Mosher. 2021. Developing Guidance Templates and Terminology to Support Multiple Traceability Objectives in the Grain Supply Chain. Cereal Chemistry, 98(1), 52-69. Was a 2021 'Editor's Pick" for Cereal Chemistry – one of 12 published articles selected by Cereal Chemistry's Editor-in-Chief as part of the "year in review".

Sharma, R., C.R. Hurburgh, and G.A. Mosher. "Vulnerability analysis using evidence-based traceability in the grain supply chain." Under review by *Cereal Chemistry*.

Pizarro, M., G.A. Mosher, and E.L. Bowers. 2021. Isolation and segregation of non-GM feed: A cost estimation model. Presented virtually at American Society of Agricultural and Biological Engineers (ASABE), July 2021.

Gupta, P., C.R. Hurburgh, E.L. Bowers, and G.A. Mosher. 2020. An analytical modeling approach for the risk assessment and estimation of the adventitious presence of GM grain in a non-GM feed supply chain. Presented virtually at Cereals & Grains Association, November 2020.

Gupta, Priyanka. Strategies for non-GM segregation in the U.S. grain and feed supply chain. Doctoral dissertation, August 2021.

## Funding Sources

American Feed Industry Association (Bowers, Hurburgh, and Mosher)

2016 Anderson Team Research Program (Mosher)

National Institute of Standards and Technology (NIST) (Mosher and Hurburgh)

## Title

Advanced Modeling of Stored Grain Ecosystems for Cable-free Grain Storage Management.

## By

Maier, D.E., Professor, Agricultural & Biosystems Engineering, Iowa State University
Wright, J.J., Graduate Research Assistant, Agricultural & Biosystems Engineering
Brumm, T.J, Professor, Agricultural & Biosystems Engineering
Rosentrater, K.A, Associate Professor, Agricultural & Biosystems Engineering

## Research Updates/Outputs

Monitoring the quality of stored bulk grain has generally done using temperature cables hung from silo roofs. This poses several challenges with costs, interference with stir-drying, and a lack of rapid spoilage detection. New wireless monitoring systems aim to solve these problems by replacing temperature cables with headspace and plenum sensors that monitor temperature, relative humidity, and $CO_2$ concentration. The new system needed to monitor grain conditions, make aeration decisions, and provide warnings of grain spoilage in time to act. A pseudo-3D finite volume method computational model with boundary conditions based on local weather data will predict grain conditions in real-time. The temperature and moisture diffusion model will account for variable diffusivity, evaporative cooling, conduction, and natural convection. The boundary conditions model will account for solar radiation and forced convection due to wind. Early grain spoilage detection will come from the analysis of $CO_2$ sensor readings.

Validation of the model will be done with corn stored in bins at the ISU Agricultural Engineering and Agronomy Research Farm. The 20,000 bushel and 14,000-bushel bins are equipped with temperature and moisture cables in addition to the Amber Ag system monitoring and fan control system. A nearby weather station will record weather data to run the model for comparison to the temperature and moisture cables. Once the model has been validated, it will be used commercially by Amber Ag and academically by ISU for teaching and research. This model will also be implemented in the bins at the new ISU Kent Corporation Feed Mill and Grain Science Complex.

## Funding Sources

National Science Foundation – SBIR grant to Amber Ag

Iowa Agriculture and Home Economics Experiment Station

## Publications

Industry Journal Articles

Maier, D.E., & Wright, J.J. 2021. Grain Storage Management – Number and Placement of Temperature Sensors and Cables Needed for Effective Monitoring of Stored Grain Quality. In *World Grain.* December 2021 Issue.

Oral Presentations

Sserunjogi M., G. Obeng-Akrofi, D.E. Maier and J. Varikooty. Monitoring and Managing Stored Grain Quality with Novel Wireless Sensing and Fan Control Technology. ASABE 2021 Virtual Annual International Conference, July 12 - 16, 2021.

Lawrence J., G. Obeng-Akrofi and D.E. Maier Effect of Fan Positions in the Plenum of Grain Bin on the Uniformity of Airflow Distribution through the Grain Mass during Natural Air Drying Using CFD Modeling. ASABE 2021 Virtual Annual International Conference, July 12 - 16, 2021.

## Title

Marketing and Delivery of Quality Grains and BioProcess Coproducts.

## By

Siliveru, K., Kansas State University
Bhadriraju, S.
Phillips, T.
Campabadal, C.

## Accomplishments and Impacts

The broader objectives of the NC-213 project are: 1) to measure, model, and assess factors which influence quality and safety attributes in the post-harvest usage, drying, handling, and distribution of cereal grains and oilseeds; 2) to improve management and operational systems to increase efficiency, retain quality, enhance value, and preserve food safety in the farm-to-user supply chain; and 3) to work with multi-institutional colleagues to improve the cereal grain and oilseed supply chain by creating measurable impacts that preserve quality, increase value, and maintain food safety / food security.

Research in 2021 studied improved methods to detect and monitor stored product pests in various habitats, evaluate the efficacy and practicality of fumigant alternatives to phosphine and methyl bromide as well as the efficacy and practicality of food safe materials to protect these commodities. Fumigants studied included phosphine ($PH_3$) with regard to diagnosis of resistance in lesser grain borer, *Rhyzopertha dominica* (Afful et al. 2021), and sulfuryl fluoride (SF) for efficacy against both the red-legged ham beetle, *Necrobia rufipes* and the mold mite, *Tyrophagus putrescentiae*. SF was easily effective for all life stages of *Necrobia* within the label rate, but as with many other insects, we did not get satisfactory control of mite eggs at a very high dose, one that was equal to about 3-times the allowable label rate (Hasan et al., 2021). We began work on the so-called liquid fumigants, propylene oxide (PPO) and ethyl formate (EF) as relatively safer fumigant alternatives to the more dangerous SF and PH3. Work with PPO and EF are still ongoing, but an initial study using PPO in combination with SF was able to give good control against the most serious stored product quarantine pest, khapra beetle (KB), *Trogoderma granarium*,, when applied in combination with SF (Myers et al. 2021). It is critical that KB be kept out of the USA; methyl bromide (MB) was the only fumigant used over many decades. Since the post-harvest uses of MB are now banned under the US Clean Air Act and the international Montreal Protocol, quarantine regulators face the possibility that MB may soon be unavailable for quarantine. The finding that PPO + SF combined are effective for KB is very important. Work on quarantine treatments at KSU in collaboration with USDA APHIS PPQ will continue into 2022 to 2023.

Several research projects looked at safe methods for use in integrated pest management of storage pests. Contact toxicity and repellent activity of safe plant-based compounds were analyzed. The mosquito repellent DEET and the fatty acid mixture of octanoic, nonanoic, and decanoic (C8910) acids were also evaluated as safe repellents and toxicants. These food-safe compounds were repellent to *R. dominica* and the cigarette beetle, *L. serricorne*, and showed promise for commercial application as organic insecticides for several pests (Manu et al. 2021). The life history and general biology of *Necrobia rufipes* was documented in more detail than in the past, and gave information useful for pest management of this beetle in the future (Hasan et al., 2021). Insect trapping is very important for detecting and monitoring stored product pests for relative numbers over time and locations in a building. Doud et al. (2021) showed how traps could be used to monitor grain pests in flour mills before and after structural fumigation to determine fumigation efficacy. Results confirm that fumigation may not be full-proof as flour mill traps detected insects within a few weeks of treatment. Our work with food safe methods to keep the

insidious mite *T. purtresenteae* off of high value commodities found one more food-safe compound, chitosan, for addition to anti-mite nets (Shao et al., 2021).

We are also evaluating the effect of two new silica dusts supplied by Imerys Chemicals, Lompoc, California, in managing insects on concrete surfaces (to simulate farm bins) and on various stored commodities (example, wheat and corn) against damaging stored product insects. Prior to testing the efficacy of the silica dusts, the particle size analysis of the two silica dusts was carried out by using Morphology G3-ID morphologically directed Raman system (Malvern Instruments, Worcestershire, UK). The particle size and shape of the two silica dusts was assessed by considering the CE mean diameter of number of particles distributed, HS circularity and aspect ratio. The mean CE diameter (2.59 µm) of the silica 1 dust particles was higher compared to silica dust 2 (1.98 µm). On the other hand, the mean HS circularity (0.602) and aspect ratio (0.568) of the silica dust 1 was comparatively lower than silica dust 2 with 0.606 and 0.634 as their respective mean HS circularity and aspect ratio. The results suggested that among the two silica dusts analyzed for particle size and shape, the silica dust 2 had smaller size distribution and had more circular particles compared to silica 1 and anticipated to have better insect mortality. The efficacy of the two silica powders have been evaluated against four stored product insect species namely, the red flour beetle (*Tribolium castaneum*), confused flour beetle (*Tribolium confusum*), lesser grain borer (*Rhyzopertha dominica*) and sawtoothed grain beetle, (*Oryzaephilus surinamensis*). The results of the experiments conducted with the two amorphous silica powders are encouraging and showed species specific responses. The adults of *T. confusum, R. dominica* and *O. surinamensis* were found to be more susceptible to silica 2 dust with concentrations above 4.0 g/ $m^2$ exposed for 24 h in the concrete treated arena experiments. On the other hand, the adults of *T. castaneum* were more susceptible to silica 1 dust leading to complete mortality at concentrations above 3 g/$m^2$ exposed for 24 h. Complete inhibition of progeny production was observed over treatment to silica dust 1 at concentrations above 2 g/$m^2$ for 24 h in *T. castaneum* as compared to silica dust 2 which required a concentration of 2.5 g/$m^2$ and an exposure time of 36 h. For tests with *R. dominica*, silica dust 2 was found to be more effective to inhibit the progeny production, requiring concentrations of 3.5 g/$m^2$ , and an exposure time of 24 h. Similar results were observed for the experiments involving *T. confusum* and *O. surinamensis* where silica dust 2 inhibited the progeny production at a lower concentration of 3.0 g/$m^2$ exposed for 24 h respectively. In continuation to the experiments to evaluate the efficacy of silica dust against stored-product insects on concrete treated arenas, the efficacy of the silica dust on stored product insects will be evaluated by admixing with stored food grains. The present experiments will show the efficacy of two amorphous silica powders on major stored grain insects on concrete surfaces and as on commodities, and we will document any adverse effects on grain physical properties at various concentrations.

## Publications

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Doud, C.W.; Cuperus, G.W.; Kenkel, P.; Payton, M.E.; Phillips, T.W. 2021. Trapping *Tribolium castaneum* (Coleoptera: Tenebrionidae) and other beetles in flourmills: evaluating fumigation efficacy and estimating population density. Insects, 12, 144. https://doi.org/10.3390/insects12020144

Hasan, M. M., Aikins , M. J., Schilling, M. W. and Phillips, T. W. 2021. Sulfuryl fluoride as a methyl bromide alternative for fumigation of *Necrobia rufipes* (Coleoptera: Cleridae) and *Tyrophagus putrescentiae* (Sarcoptiformes: Acaridae), major pests of animal-based stored products. J. Stored Prod Res. Vol 91 online https://doi.org/10.1016/j.jspr.2021.101769

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Hasan, M. M., Aikins, M. J., Mahroof, R. M. and Phillips, T. W. 2021. Effects of diet and temperature on the life history of the red-legged ham beetle, *Necrobia rufipes* DeGeer (Coleoptera: Cleridae). Environ. Entomol. 51: 278–285 https://doi.org/10.1093/ee/nvab116

Shao, W., Campbell, Y. L., Phillips, T. W., Freeman, C., Kundu, Crist, C. A., Williams, J. B. and Schilling. W. M.. 2021. The application of chitosan in food-grade coatings to control *Tyrophagus putrescentiae* on dry-cured hams and the effects on sensory properties. J. Stored Prod. Res. 94:101899. https://doi.org/10.1016/j.jspr.2021.101899

Yao, K. D., Bh. Subramanyam, and R. G. Maghirang. 2021. Moisture content and application rates of inert dusts: Effects on dust and wheat physical properties. Food Research (in press).

Yao, K. D., Bh. Subramanyam, K. Siliveru, J. Anthony, and R. G. Maghirang. 2021. Using the FT4 Powder Rheometer to characterize bulk and dynamic flow properties of Hard Red Winter wheat (HRW) treated with three amorphous silica dusts. Journal of Stored Products Research (in press).

Pulivarthi, M.K.,E. Nkurikiye, J. Watt, Y. Li, and K. Siliveru. 2021. Comprehensive understanding of roller milling on the physico chemical properties of red lentil and yellow pea flours. *Processes* (Accepted for publication).

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Buenavista, R. M. E., K. Siliveru, and Y. Zheng. 2021. Utilization of dried distiller's grain with solubles: A review. *Journal of Agriculture and Food Research*, 5, 100195.

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## Title

Lab Scale Study of Quality Changes in Wheat Stored under Conventional and Hermetic Conditions.

## By

Montross, M.D., University of Kentucky
McNeill, S.G.
Kehinde, B.

## Outputs

Hermetic (oxygen limited) storage systems have been proposed as an alternative to conventional storage with uncontrolled atmospheric air. Wheat was placed in experimental containers to simulate hermetic and conventional storage to evaluate quality changes. Abiotic-stressed germination is a method to change food functionalities and this was evaluated for each storage condition over time.

Studies conducted have indicated changes in compositional profiles of stored grains based on treatments associated with the presence/absence of air. These studies were conducted at three temperature levels, with four varieties, and three storage times. After storage, changes in where were evaluated. Preliminary results have been completed. For instance, alpha-amylase, an important enzyme to baking and malting industries was observed to change within a 3-month storage period at 10°C. In most cases, the alpha-amylase activity was reduced after 3 months of storage. This reduction was more pronounced in conventional storage compared to hermetic. Germination has been hypothesized to induce desirable changes in grain related to its food and nutritional profile. Initial results from this study have indicated that germination increased the biologically functional fatty acid methyl esters content, namely omega-3 (C18:3n3) and 11-Eicosenoic acids (C20:1), with an overall decrease in the fat content of the grains.

## Outcomes/impacts

The data will allow farmers/processors to evaluate alternative storage conditions and minimize quality reduction and economic costs. It will also provide additional processing techniques to add value and nutrition to wheat.

## Title

Mechanisms and Mitigation of Dust Generation During Grain Handling and Processing.

## By

Ambrose, R.P.K., Department of Agricultural and Biological Engineering, Purdue University
Yumeng Zhao, Y.

Maghirang, R.G., Department of Agricultural and Biological Engineering, University of Illinois at Urbana-Champaign

Casada M.E., USDA-ARS, CGAHR, Manhattan, Kansas

Petingco, M., Kansas State University

## Outputs

Corn is the largest crop grown in the U.S. and supplies most food, feed, fuel ethanol, and pharmaceutical industries. Due to the large and growing volume of grains handled, and based on the nature of grain handling and processing equipment, there is an increased hazard to the health and safety of workers from the dust generated. On average, 1 metric tonne of grain contains about 1-5 kg of dust, which can lead to serious health concerns if inhaled. Although considerable efforts and resources have been spent studying grain dust explosions, the data indicate little progress in preventing dust explosion. The essential role of grain dust in causing grain dust explosions is clearly established, but there is limited understanding of the adhesion mechanism of dust particles onto the grain and surfaces, the mechanism of separation of dust from grain kernels, their inter-particle bonds, and the dispersion pattern of grain dust. Therefore, the objective of this study is to use fundamental tools and engineering concepts to study the mechanisms of dust generation during handling and processing of corn.

The adhesion force that holds grain dust particles to the grain itself is an important factor in better understanding and mitigating dust separation from grain kernels and the resulting dust cloud generation. Results showed large variability in dust concentration between the corn samples tested in this study. The dust particle attachment strength ranged from less than $4.6 \times 10^{-10}$ N to $2.1 \times 10^{-8}$ N. In addition, results showed that freshly harvested corn samples contained a higher presence of small particles with low circularity than older, lower quality samples. The dust particles that were more strongly attached to corn kernels tended to have lower surface roughness than those that were weakly attached for the freshly harvested grain. During loading and unloading, the grain kernels' kinetic energy increases and then a sudden energy loss due to collision or friction causes the dust particle to separate from kernels. In order to find out ways to suppress dust emission, a discrete element model (DEM) was developed, and experiments were conducted using corn kernels on determining the emission rates of total suspended particulates (TSP) at three-grain flow rates and three drop heights during receiving operation at a grain elevator. Corn kernel's energy changes during the unloading process were obtained from DEM simulation, and the TSP emission rate was calculated based on corn energy loss from every collision and measured dust particle size distribution.

## Outcomes/Impacts

Results indicated that reducing the airflow turbulence reduced the amount of dust separated from corn kernels during gravity handling. The findings from this study would help design of dust collection systems, specifically at the grain transfer points.

## Funding Sources

USDA-AFRI

## Contact

Ambrose Rose Prabin Kingsly, Agricultural & Biological Engineering, 225 S. University Street, West Lafayette, Indiana, 47907. rambrose@purdue.edu

## Title

Near Infrared Spectroscopy Utilization in Grains, Cereals and Seeds.

## By

Armstrong, P., Stored Product Insect and Engineering Research Unit, Center for Grain and Animal Health Research, Manhattan, Kansas

## Outputs

Maize Haploid Classification using Single Kernel Near-Infrared Spectroscopy

Doubled haploids (DHs) seeds have become an important breeding tool for creating maize inbred lines by reducing the time to develop these lines by several years. However, several bottlenecks in the DH production process limit wider development, application, and adoption of the technique. Haploid kernels are typically sorted manually from a much larger pool of hybrid siblings which introduces time constraints on DH production. Automated sorting based on the chemical composition of the kernel can be effective but have not achieved the necessary sorting speed to be cost-effective replacement over manual sorting. Single kernel near-infrared reflectance (skNIR) spectroscopy was evaluated as a platform to accurately identify haploid kernels. The skNIR platform is a high-throughput device that acquires a NIR spectrum and weight from each kernel to sort DHs from hybrid kernels. With this system we were able to enrich the haploid selection pool to above 50% haploids which would make a final manual sort be performed more quickly on a substantially smaller lot of kernels. Automation a single kernel NIR system for sorting has been completed deployed at Iowa State and the University of Florida. IMPACT: Being able to develop inbred lines more quickly would have a huge impact on hybrid maize development by being able to produce more inbred lines, with differing traits more quickly.

Flax and Sorghum: Multielement Content and Nutritional Value within Varieties and their Potential Selection for Future Climates to Sustain Food Security Dietary Guidelines for Americans recommends giving priority to nutrient dense foods while decreasing energy-dense ones. Both flax (Linum usitatissimum) and sorghum (Sorghum bicolor) are rich in various essential minerals. Previous studies have shown that elevated CO2 levels could reduce key nutrients in crops. In this study, 102 flax and 108 sorghum varieties were analyzed to investigate their ionome diversity and elemental level interactions. The results showed substantial genetic variation and elemental correlation in flax and sorghum. A serving size of 28 g of flax typically delivers 37% of the daily value (DV) for Copper, 31% for Manganese, 28% for Magnesium, and 19% for Zinc, while sorghum delivers 24% of Manganese, 16% of Copper, 11% of Magnesium, and 10% of Zinc. We identified a set of flax and sorghum varieties with superior seed mineral composition that could complement breeding programs in improving nutritional quality of flax and sorghum. IMPACT: Overall, we demonstrate additional minerals data and their corresponding health and food security benefits within flax and sorghum that could be considered by consumers and breeding programs for facilitating improvement for seed nutritional content.

## Publications

Hacisalihoglu, G., P.R. Armstrong. Flax and Sorghum: Multi-Elemental Contents and Nutritional Values within 210 Varieties and Potential Selection for Future Climates to Sustain Food Security. Plants 2022, 11, 451. https://doi.org/10.3390/plants11030451

## Funding and Grants

In-house CRIS Project#3020-43440-008-00D “Impacting quality through preservation, enhancement, and measurement of grain and plant traits”

USDA 1890 Faculty Research Sabbatical Program. Development of near infrared spectroscopy (NIRS) measurements for single seed oil and protein of sorghum and flax.

## Title

Developing New Stored Grain Pack Factors.

## By

Casada M.E., USDA-ARS, CGAHR, Manhattan, Kansas

Petingco, M., Kansas State University, Department of Biological and Agricultural Engineering

Thompson, S.A., University of Georgia, Department of Biological and Agricultural Engineering

McNeill, S.G., University of Kentucky, Department of Biosystems and Agricultural Engineering
Montross, M.D.

Turner, A. P., Clemson University, Department of Agricultural Sciences

Maghirang, R.G., University of Illinois at Urbana-Champaign, Dept. of Agricultural and Biological Engineering

## Outputs

The grain industry requires accurate stored grain bulk density values to estimate the mass of grain in bins for design, inventory, and auditing purposes. However, bulk density of grain in a storage bin increases with the overbearing pressure of the grain and varies widely depending on kernel properties and handling processes such as grain fall height, filling rate, and use of a spreader as compared to spout filling. Existing experimentally based predictions of compacted bulk density are often inaccurate because of the wide range of grain properties and storage and handling conditions included, making theoretical prediction methods, such as the discrete element method (DEM) of modeling more desirable. DEM evaluates the movement and interactions of each particle, making it effective for studying how handling processes and material properties affect the bulk density and requires knowledge of the effect of particle shape and contact parameters (such as coefficients of friction) on modeling particle systems like wheat bulk density.

We developed grain kernel sub-models, required for accurate DEM simulations, based on laboratory measurements and simulations of loose-fill bulk density and used the grain kernel models to evaluate bulk density simulation methods. For the particle sub-models, calibrating the contact parameters for each size fractions resulted in accurate simulated bulk densities in comparison to experimental results. Experiments and simulations showed that the bulk density was higher for particles having lower aspect ratio and smoother surfaces, showing that it is important to capture the true shape of particles being modeled to accurately predict grain bulk density. We found that accurate material property measurements for key properties, the particle-to-particle coefficients of static and rolling friction, improved the prediction of grain bulk density as affected by different handling processes. The more shape-accurate particle model, based on five spheres, was better for capturing the heap profile of wheat observed in the experiments but has the disadvantage of larger computational effort compared to the simple spherical particle model. Wheat compaction under confined uniaxial compression was modeled using DEM to determine the effect of overburden pressure on wheat bulk density. Results showed that the appropriate time step, grid size, and pressure loading rate were critical parameters to control to avoid instabilities and obtain valid results. The resulting DEM simulated bulk densities agreed with experimental values at low overburden pressure (below 48 kPa) and tended to overpredict at higher pressures (Figure 1).

## Outcomes/Impacts

These results provide better understanding of the influence of particle shape, contact parameters, drop height, overburden pressure, and size distribution on bulk density and provided an effective approach to simulating wheat bulk density as affected by different handling practices. Effective particle models have been defined with three size fractions for simulating container filling operations with modeling attributes selectable for optimizing computational cost versus surface profile accuracy. Resulting models can be used to provide the industry with better estimates of stored grain compaction, improving the accuracy of audits, insurance adjustments, and bin designs.

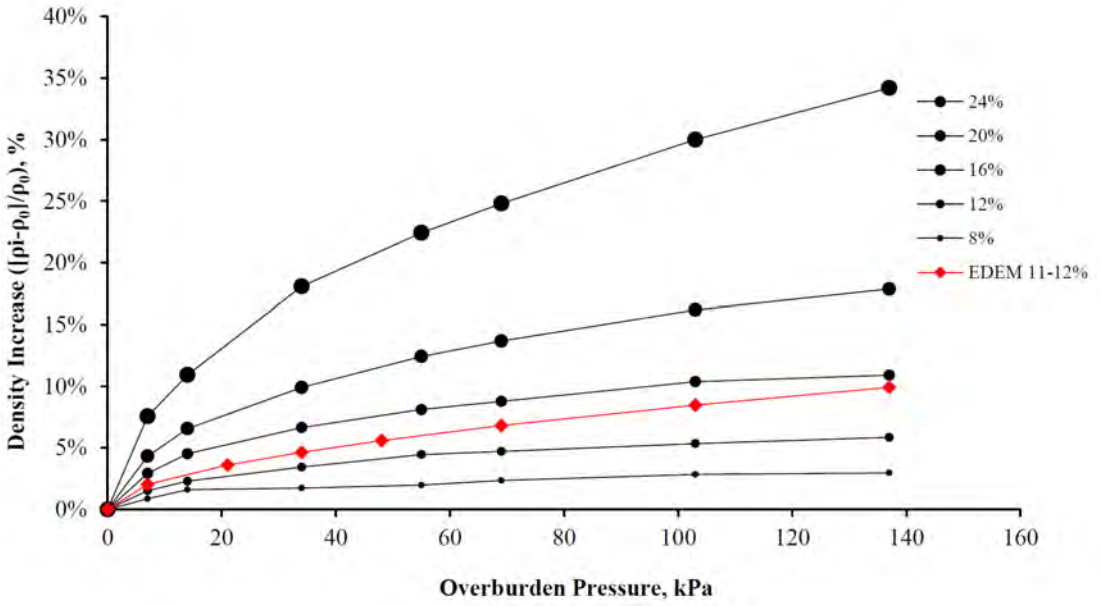


**Figure 1.** DEM predicted density increase of wheat density compared to experimental density increase of Thompson and Ross (1983); soft red wheat at different moisture levels (% wet basis).

## Publications

Petingco, M.C., M.E. Casada, R.G. Maghirang, R.P.K. Ambrose, O. Fasina. 2020. Influence of particle shape and contact parameters on DEM-simulated bulk density of wheat. Transactions of the ASABE. 63(6): 1657-1672.

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Elsayed, S., M.E. Casada, R.G. Maghirang, M. Wei. 2021. Evolution of phosphine from aluminum phosphide pellets. Transactions of the ASABE. 64(2): 615-624.

**NC-213 (The U.S. Quality Grains Research Consortium)**

Objective 3: To work with multi-institutional colleagues to improve the cereal grain and oilseed supply chain by creating measurable impacts that preserve quality, increase value, and maintain food safety/food security.

## Title

Grain Safety Program.

## By

Issa, S.F., University of Illinois

## Outputs

Developed training material for grain elevator workers and conducted in-person and virtual trainings. Developed list of all existing strategies to clear out grain bins.

## Outcomes/Impacts

Held multiple workshops on grain safety both virtually and in-person and trained over 500 workers across the US. Tested the effectiveness of compressed air in removing crusted grain from grain bins. Investigating and documenting all existing strategies to remove out-of-condition grain allows us to disseminate state of best practices and investigate which of these strategies are more effective against each type of grain entrapments.

## Publications

Issa, S.F., Gaither, D., Raza, M.M., & Field, W.E. (2021) Exploring Alternative Prevention Solutions to Reduce Grain Entrapments. Presented at American Society for Agricultural and Biological Engineers Annual Meeting, July 2021. Virtual

## Title

Determining Corn Quality across Iowa over Two Years of Extreme Weather Conditions.

## By

Hurburgh, C.R., Professor, Iowa State University
Bowers, E., Adjunct Assistant Professor
Branstad, E., Graduate Research Assistant

Personnel from the Iowa Department of Agriculture and Land Stewardship (I.D.A.L.S.)

## Outputs

The Iowa Department of Agriculture and Land Stewardship routinely samples Iowa corn on a county by county basis to determine if mycotoxins are a significant hazard in that year. In the last two crop years, 2020 and 2021, more than half of Iowa counties have experienced drought conditions. In 2020 a massive storm with 100-140 mph winds crossed the center of the state from end to end, affecting about 13 million acres of row crops just before maturity was reached. Much of the storm area was also included in the drought coverage. The IDALS samples from 2020 and 2021 were analyzed for protein, oil, starch, density and test weight.

## Impacts

In 2020, the drought area samples were 0.5 % points higher in protein and 0.5 pounds per bushel higher in test weight than the state average. This was as expected from the smaller kernels were characteristic of drought. In the storm area, largely flattened by wind, samples were about 0.5 lb./bushel lower in test weight but not significantly different in protein. There were no samples above FDA guidance or tolerances for mycotoxins (aflatoxin, vomitoxin, zearalenone, and fumonisin). This was much less impact on quality than was expected from the level of damage observed at that time. The abnormally warm and dry weather after the storm seemed to create more grain fill and development than previously thought possible.

In 2021, the severe drought areas had reduced grain yield and had the same protein and test weight effect as in 2020. However late season rainfall in less intense drought area apparently caused recovery of kernel fill and quality to normal levels. It has been known that grain quality is determined late in the growing season, but these data demonstrated that harvest weather conditions can have more impact on the end result than previously thought. This is important for planning of grain handling and processing operations. These data are now being used for crop quality and development modelling.

## Funding Sources

The State of Iowa

Iowa Corn Growers Association

Iowa Agriculture and Home Economics Research Station

## Title

Establishment and Utilization of the new I.S.U. Feed Mill and Grain Science Complex.

## By

Maier, D.E., Professor & Director, Agricultural & Biosystems Engineering and Animal Science, Iowa State University
Ewing, A., Manager & Associate Director, Agricultural & Biosystems Engineering
Hurburgh, C.R., Professor & Associate Director, Agricultural & Biosystems Engineering
Greiner, L., Assistant Professor & Associate Director, Animal Science

## Research Updates/Outputs

The new ISU Feed Mill and Grain Science Complex is a $25 million state-of-the-art facility currently under construction. It will be unique among university facilities because it will have a self-contained feed manufacturing facility and a complete grain handling, drying and storage center. Its mission furthers ISU's research, teaching, service, Extension, and industry and international outreach in support of the global grain and feed industry. The facility is scheduled to be operational by late 2022.

The feed manufacturing facility consist of the 100-ft tall feed mill tower, the attached 3-story pelleting plant, and an adjacent building that houses the pilot plant, quality lab, warehouse, education space, and employee locker, shower and break rooms. The mill tower includes a 4,000 BPH bulk grain and ingredient receiving and loadout area, bulk weighing and cleaning tower, 10 TPH hammer mill, 10 TPH 3-high roller mill, 30 bulk ingredient storage bins with 2 to 30 T capacity, 30-bin micro ingredient batching system, a 2 TPH ribbon mixer, and the operations control room. The pelleting plant includes a 5 TPH conditioning, hygenizing, pelleting and counterflow cooling line that allows for bypassing the hygienizer, pellet mill and crumbling rolls. Feed mash or pellets can be transferred to bulk load-out, tote filling or bagging. The pelleting plant also includes the manager's office, IT/AV network room, and the feed mill automation control and monitoring room.

The pilot plant is designed for manufacturing small batches of research diets, as well as hands-on teaching and training. It contains the major unit operations including hammer mill, 2-high roller mill, several sizes of mixers, lab pellet mill, and a 1 TPH conditioner, pellet mill and counterflow cooler system. Feed mash or pellets can be transferred to tote filling or bagging. The adjacent Grain and Feed Quality Analysis Lab is equipped with moisture meters, near-infrared analyzers, laboratory ovens, sample dividers, dockage testers, test weight apparatus, weighing scales, sieve shakers, and bench top space to conduct physical properties, mycotoxin testing, feed safety, and storability analysis of corn, soybeans, DDGS, soymeal, and other grains and feed ingredients. The on-site lab is supported by the on-campus Post-Harvest Grain Engineering and Technology teaching and research labs housed in the department's state-of-the-art Sukup Hall, and by the Grain Quality Lab of the Iowa Grain Quality Initiative. The on-campus labs contain temperature and humidity-controlled growth chambers to maintain or condition samples with regard to insect growth and/or mold development, and the associated equipment to count insects, plate fungal spores to determine colony forming units, and quantify mycotoxins. The education space includes a classroom for 50, a flex work space, and a multi-purpose lobby.

The grain center consists of four 54-foot diameter 40,000-bushel storage bins to be equipped with a cloud-based monitoring and management system that utilizes temperature and moisture cables in the grain mass, and $CO_2$ sensors in the headspace and plenum areas. Aeration fans will be equipped with 23 kW motors and variable frequency drives (VFDs) to control airflow rates from 0.05 to 1.0 CFM/bu. Materials handling equipment consists of screw, drag and bucket conveyors with 4 to 37 kW motors. Electric power consumption of all motors will be monitored via the

automation system. A 42-foot diameter bin will allow for evaluation of low temperature/natural air (NA/LT) in-bin drying versus medium temperature (100-140°F) batch or layer drying versus medium temperature (120-160°F) stir-drying. The bin is equipped with a natural gas fueled burner.

The grain center will also have a state-of-the-art mixed-flow dryer with a rated drying capacity of 1,700 bushels per hour when drying corn from 25% to 15% moisture content. It is equipped with a natural gas burner that has a 10 million average BTU capacity and two blower fans with a total of 52 kW. Two 10,000-bushel hopper-bottom wet holding bins will allow for segregation of incoming corn at harvest based on moisture content (e.g., 18-22% in bin 1, 22-25% in bin 2). Segregating corn based on moisture content increases drying efficiency and improves dried grain quality. The dryer test stand will also be supplied by the two wet holding bins. The test stand will allow for plug-and-play testing of dryers from commercial manufacturers and compare results against a standard test dryer equipped with sensors to monitor performance and calibrated according to *ISO 11520-1 Agricultural grain driers - Determination of drying performance* and *ISO 11520-2 Additional procedures and crop-specific requirements*. A second dryer can be placed next to the calibrated dryer and run in parallel ensuring both dryers operate with the same incoming wet corn and under the same weather conditions monitored by an on-site station.

## Funding Sources

| | |
|---|---|
| | Iowa Corn Promotion Board |
| Kent Corporation | |
| Sukup Company | CPM Company |
| New Cooperative, Inc. | Iowa Agriculture and Home Economics Experiment Station |

Numerous equipment, gifts-in-kind and services.

## Publications

Industry Journal Articles

Maier, D.E. Causes and prevention of stored grain fires. World Grain, June 2021.

Maier, D.E. Sanitation, loading, aeration, monitoring. Grain Journal, July/August 2021.

Maier, D.E. and Wright, J. Grain storage management – Number and placement of temperature sensors and cables needed for effective monitoring of stored grain quality – Part 1. World Grain, December 2021.

Continuing Education Offerings

Advanced Grain Elevator Operations Management Short Course, Grain & Feed Association of Illinois (GFAI), Bloomington, Illinois, March 2-6, 2020. (Maier, Ewing)

Advanced Grain Elevator Operations Management – Grain Quality Management Virtual Course, Agribusiness Association of Iowa (AAI), February 15-19, 2021

An Iowa cooperative, February 22-26, 2021

Grain Elevator & Processing Society (GEAPS), May 10-15, 2021. (Maier, Hurburgh)

Grain and Feed Ingredient Analysis for Bangladesh Virtual Training Course, U.S. Grains Council, January - March, 2021. (Maier, Hurburgh)

Oral Presentations

Middle East & Africa (MEA) Feed Training Center, 18th International Marketing Conference & 61st Annual Membership Meeting, U.S. Grains Council, February 2, 2021. (Maier)

Challenges with Grain Storage and Quality Internationally – from Latin America to Africa to Asia, GEAPS Exchange Online Conference, February 23-25, 2021. (Maier)

Preserving Quality of Stored Grains and Ingredients in Hot Climates, Middle East Poultry Industry Virtual Training Course, Middle East and Africa Feed Manufacturing Training Center (Tunisia), U.S. Grains Council, May 24-28, 2021. (Maier)

Advanced Feed Manufacturing Practices: Conditioning, Pelleting, Crumbling, Middle East Poultry Industry Virtual Training Course, Middle East and Africa Feed Manufacturing Training Center (Tunisia), U.S. Grains Council, May 24-28, 2021. (Maier)

Advanced Feed Manufacturing Practices: Batching, Mixing, Grinding, Middle East Poultry Industry Virtual Training Course, Middle East and Africa Feed Manufacturing Training Center (Tunisia), U.S. Grains Council, May 24-28, 2021. (Ewing)

Practical Aspects of Feed Mill Management, Middle East Poultry Industry Virtual Training Course, Middle East and Africa Feed Manufacturing Training Center (Tunisia), U.S. Grains Council, May 24-28, 2021. (Ewing).

## Title

Outreach, Training, and Professional Development to the Grain, Feed Mill, and Processing Industry.

## By

Maier, D.E. Maier, Professor, Iowa State University
Hurburgh, C.R., Professor
Bowers, E.L., Associate Scientist III/Adjunct Assistant Professor
Hardy, C.L., Program Specialist
Anderson, K., CIRAS Program Specialist
Mosher, G.A., Associate Professor

## Outputs

A separate report outlines the development of the ISU Feed Mill and Grain Science Complex and its associated continuing education offerings.

The FSMA Preventive Controls Qualified Individual short course, led by Drs. Hurburgh and Bowers and assisted by C. Hardy, for animal feed and food continues to be offered to qualified feed industry professionals. Iowa State University partnered with industry sponsors and other professional stakeholders, such as American Feed Industry Association (AFIA).

A team including Drs. Hurburgh, Bowers, and Mosher, along with C. Hardy and K. Anderson have been collaborating to develop a standardized continuing education program on the FSC36 Safe Feed/Safe Food Certification program. The program will present core concepts to assist feed industry stakeholders implement safe food and safe feed tasks and procedures in their facilities. The program will be presented for the first time in April 2022.

Dr. Mosher worked with colleagues in Animal Science and Food Science to offer a graduate course on Food and Agricultural Traceability as part of Iowa State University's Executive MBA program in the Ivy College of Business. Thirteen students attended the condensed course, offered in August. Dr. Mosher presented information on grain and oilseed traceability, food differentiation, and tools to facilitate segregation and isolation of specialized traits.

## Outcomes/Impacts

The Grain Elevator Management course provides professional development for grain industry leadership talent and has been very popular, not only in Iowa but in other Midwestern states. FSMA Preventive Controls Qualified Individual training for Animal Foods continues to have strong demand and work has begun on a course to address more advanced topics. The FSC36 Safe Feed / Safe Food Certification program is targeted toward feed mill employees and aims to link feed-specific requirements from FSMA with feed mill requirements. It also will focus on implementation. The Executive MBA addresses an educational need for personnel working in agribusiness companies, who wish to pursue business process management in an agricultural context. Students work through a 2-year program in cohorts of 12 to 25 fellow professionals. Opportunities for field trips, a focus on governmental policy, and professional networking make the program unique among other MBA programs.

## Funding Sources

Extension Funding

Pay for service

Iowa Agriculture and Home Economics Research Station

## Title

Preserving Economic Value of Bulk Commodities within Changing Pest Landscapes in Montana.

## By

Weaver, D., Montana State University

## Outputs

Research projects have been developed and either published, under review, or in progress that directly relate to Objectives 2 and 3. The works "Stability analysis of stem solidness, grain yield and grain protein concentration in spring wheat" and “Plant volatiles and oviposition behavior in the selection of barley cultivars by wheat stem sawfly (Hymenoptera: Cephidae)” characterize features of pest management that relate to use of wheat and barley by the wheat stem sawfly. Specifically, we further consider how cultivar variation can be manipulated into stabilizing yield and quality of barley on the landscape and we also explore potential interactions between wheat protein content and the degree and stability of pith expression in solid-stem cultivars developed to manage this pest.

There are two key concerns that arise from use of barley by the wheat stem sawfly. Montana remains 3rd in production of barley in the US. Significant decreases in yield could have a negative impact on returns for the bulk availability of barley for malt, feed and seed production. Moreover, the potential risk to barley production for the malt industry is likely more grave. The wheat stem sawfly mines stems and impacts vascular flow of nutrients during grain fill. Typically this results in decreased yield in the form of decreased amounts of endosperm – at least in wheat. This causes stable or increased levels of protein relative to carbohydrates. In wheat, this leads to some potential for offsetting loss with a protein premium for wheat marketed in the bread class. Malt barley is more vulnerable because increased protein as a result of loss of “plumpness” is anathema in malt barley. The malt class is met by plump grains with low protein and wheat stem sawfly directly counters this. In addition, growers impacted by wheat stem sawfly in wheat crops frequently grow solid-stem cultivars to provide a modicum of resistance to this pest. Growers and end users alike have concerns about protein content. At issue are premium returns for high protein content that can be provided at the elevator, especially in spring wheat.

In addition, a presentation entitled “IPM of stored-grain insects” was presented face-to-face at the Montana State University Extension Ag and Natural Resources Spring Update, Lewistown, Montana on May 18. This presentation created eligibility for pesticide applicator recertification credits. Relative isolation due to COVID-19 concerns may have created a gap in knowledge about safe storage of newly-harvested commodities. In particular, there are ongoing concerns about aeration protocols for bulk storage of wheat in large volume bags near bins. Although these can be aerated, early snowfall can create issues with moisture content.

## Outcomes/Impacts

Research in barley has clearly identified that barley is now readily used by wheat stem sawfly, but there is varietal variation in host plant susceptibility that can be utilized to breed for greater level of antixenosis and antibiosis, as well as potential influence on tritrophic inputs from beneficial parasitoids. One other key finding is that the cultivar “Hockett” is more suited for wheat stem sawfly population growth and development, and we recommend that growers seeing increased stem cutting discontinue planting this popular and otherwise desirable cultivar. We also have shown that the greater attraction to “Hockett” is due to increased amounts of host plant volatiles that are attractive.

For stability of solid-stem wheat it was generally seen that protein content was not linked to this character and variation tends to follow the pattern of cultivar specific determination. In general, all current varieties have acceptable levels of grain protein, which tend to be increased under wheat stem sawfly pressure, with a concomitant potential decrease in yield and test weight – especially under dry conditions.

## Publications

Subedi, M., H. A. Carcamo, J. J. Knodel, D. K. Weaver, R. D. Cuthbert, C. J. Pozniak, K. T. Nilsen, and B. L. Beres. 2021. Stability analysis of stem solidness, grain yield and grain protein concentration in spring wheat. *Canadian Journal of Plant Science 101(4): 456-475*

Achhami, B. B., G. V. P. Reddy, M. L. Hofland, J. D. Sherman, R. K. D. Peterson, and D. K. Weaver. 2021. Plant volatiles and oviposition behavior in the selection of barley cultivars by wheat stem sawfly (Hymenoptera: Cephidae). *Environmental Entomology 50(4): 940 -947.*

Weaver, D. K. 2021. IPM of stored-grain insects. Montana State University Extension Ag and Natural Resources Spring Update in Lewistown, Montana, May 18.