NC-213

(The U.S. Quality Grains Research Consortium)

2019 ANNUAL PROGRESS REPORTS

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MARKETING AND DELIVERY OF QUALITY GRAINS AND BIOPROCESS COPRODUCTS

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The NC-213 Industry Advisory Committee consists of at least five NC-213 stakeholder members recruited by and voted on by the NC-213 Executive Committee to serve a two-year term each. This committee serves in an advisory role to NC-213, its Executive Committee and its membership. In addition, the committee serves as a reviewer pool for The Andersons Grant Review Committee, acts as a liaison between NC-213 researchers and the industry, actively encourages existing industry stakeholders and recruits new industry stakeholders to participate in NC-213 and provides active feedback regarding research agenda and results. Current members are listed below:

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

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NC-213 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.

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[1] Please note that some reports have more than one contributing institution and author. In the Contents, only the principal investigator, along with their institution, is listed. Please refer to the individual report for a complete list.

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

Determination of Lysine Concentration in Animal Feed Ingredients using Near-infrared Hyperspectral Imaging.

By

Princess Tiffany G. Dantes, Iowa State University
Charles R. Hurburgh

Outputs

Knowing the available amino acids in animal feed will increase formulation efficiency in animal diets and will contribute to sustainable use of feed materials, effective quality control, reduced cost in production, and appropriate pricing for feed ingredients. In addition to the labor-intensive and slow chromatographic methods, non-destructive methods, such as near-infrared spectroscopy (NIRS) and regression equations based on crude protein, are being used to estimate amino acid concentration. Both alternative methods are reported to depend on the protein content and to estimate protein instead of amino acid. Near-infrared hyperspectral imaging (NIR HSI), a combination of NIRS and machine vision, provides spectral (chemical composition) and spatial (location) characteristics of a sample. NIR HSI is being used in food and feed quality and safety applications, particularly in detection and classification. The ability of NIR HSI to produce spectra on a pixel by pixel basis provides an advantage over the usual NIRS, specifically in products which are highly variable and of low concentration such as amino acids in feed ingredients. Lysine concentration was determined in three different major feed ingredients (soybean meal, dried distiller's grains with solubles and ground corn) using NIR hyperspectral imaging. The spectrum of pure lysine was superimposed on the spectra of the ingredient samples to identify the contribution of lysine alone at individual pixel locations.

Outcomes/Impacts

Because lower protein soybeans typically result in higher concentrations of essential amino acids in soybean meal, despite the lower crude protein, this work is intended to improve the competitiveness of US soybeans and meal from US soybeans, in the face of higher crude protein levels from major competitors. Analytics have been a major stumbling block in the promotion of amino acid profile advantages to international buyers.

Funding Sources

Corning Optics, Inc.

Contacts

Princess Tiffany G. Dantes, Graduate Research Assistant, pgdantes@iastate.edu, +1-515-520-4532

Title

Hyperspectral/Multispectral Imaging Methodology to Measure Fungal Growth and aflatoxin in Maize

By

Yao, Haibo, Geosystems Research Institute/Mississippi Agricultural & Forestry Experiment Station, Mississippi State University

Objectives

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

Outputs

Corn kernels infected with aflatoxin producing and non-producing Aspergillus flavus were collected from lab inoculation experiments. The treated kernels have different incubation durations post lab inoculation. The infected kernels were imaged with a tabletop shortwave near infrared (SWIR) hyperspectral scanning imaging system (1,000 - 2,500 nm). The germ and endosperm sides of the corn kernels were imaged separately. In the meantime, the actual aflatoxin content was determined using a destructive approach for reference purpose. Image processing algorithms were developed to incorporate with the imaging system for rapid detection of aflatoxin contamination and toxigenic fungi infection with the SWIR system.

Outcomes/Impacts

The focus is on the development of rapid, non-destructive technologies for fungal infection and aflatoxin detection in grains. Aflatoxin is a naturally occurring toxin, found in grain crops and products. It is regarded as one of the most important food safety problems in the world. Maize contaminated with toxigenic strains of A. flavus can result in great losses to the agricultural industry and pose threats to public health. The research effort aims at providing a rapid, non-destructive method for screening maize at elevators or grain collection points, identifying and diverting contaminated grain into alternative uses, thereby protecting the food supply and increasing producer profitability. Results from the current study enhanced the potential of using fluorescence multispectral imaging for the detection of fungal infected and aflatoxin contaminated maize.

Publications

Hruska, Z., Yao, H., Kincaid, R., Tao, F., Brown, R.L., Cleveland, T.E., Rajasekaran, K., Bhatnagar, D. Spectral-based screening approach evaluating two specific maize lines with divergent resistance to invasion by aflatoxigenic fungi. Frontiers in Microbiology -https://doi.org/10.3389/fmicb.2019.03152

Tao, F., Yao, H., Hruska, Z., Liu, Y., Rajasekaran, K., Bhatnagar, D. (2019). Detection of aflatoxin B1 on corn kernel surfaces using visible-near infrared spectra. Journal of Near Infrared Spectroscopy. https://doi.org/10.1177%2F0967033519895686

Tao, F., Yao, H., Zhu, F., Hruska, Z., Liu, Y., Rajasekaran, K., Bhatnagar, D. (2019). A rapid and nondestructive method for simultaneous determination of aflatoxigenic fungus and aflatoxin contamination on corn kernels. Journal of Agricultural and Food Chemistry, 67(18), 5230-5239.

Han, D., Yao, H., Hruska, Z., Kincaid, R., Rajasekaran, K., Bhatnagar, D. (2019). Development of high speed dual camera system for batch screening of aflatoxin contamination of corns using multispectral fluorescence imaging. Transaction of the ASABE, 62(2), 381-391.

Tao, F., Yao, H., Hruska, Z., Liu, Y., Rajasekaran, K., Bhatnagar, D. (2019). Use of Visible–Near-Infrared (Vis-NIR) spectroscopy to detect aflatoxin b1 on peanut kernels. Applied Spectroscopy, 73(4), 415-423.

Yao, H., Tao, F., Hruska, Z., Kincaid, R., Rajasekaran R., Bhatnagar, D. 2019. Detection of aflatoxin contamination in maize kernels using shortwave infrared (SWIR) hyperspectral imaging. 19th International Conference on Near Infrared Spectroscopy. ICNIRS-. Gold Coast, Australia, Sep. 15 – 20, 2019.

Yao, H. 2019. Optic methods for rapid and non-invasive detection of aflatoxin contamination in corn. OSA Incubator on Agri-Photonics: Advanced Spectroscopy in Precision Agriculture. Washington, D.C. 5/13/2019.

Tao, F., Yao, H., Hruska, Z., Kincaid, R., Rajasekaran, K., Bhatnagar, D. (2019). Potential of near-infrared hyperspectral imaging in discriminating corn kernels infected with aflatoxigenic and non-aflatoxigenic Aspergillus flavus. SPIE Defense + Commercial Sensing. Paper No. 1101603. Baltimore, MD.

Funding Source(s)

USDA/Mississippi State University Cooperative Agreement

Title

Physicochemical and Genetic Approaches to Improve Microbiological and Chemical Safety of Grain and Grain Products.

By

Devin J Rose, University of Nebraska-Lincoln

Outputs

As an important part of the economy of Nebraska, it is imperative to maintain a high demand for healthy, safe wheat. Recently, however, the safety of wheat has been an area of question. In this proposal, we aim to address wheat safety from three perspectives: 1) microbiological safety; 2) reduction in free asparagine, a precursor to acrylamide, a toxin; and 3) reduction in total and bioavailable cadmium, a toxic heavy metal. Each of these Nebraska-specific objectives clearly support the overall multistate objectives, which are focused on quality and safety of grains. In objective 1 we will evaluate the efficacy of a new steam-treatment to obtain microbiologically safe wheat without affecting end-use quality. In objective 2 we will identify cultivars and management practices that Nebraska farmers can adopt to reduce free asparagine in grain without sacrificing yield or quality. This will be accomplished through a survey of commercial wheat production and farmer management practices. In objective 3 we will determine cultivars and processing methods that increase potential bioavailability of essential mineral elements from wheat while minimizing cadmium. This project targets wheat producers, wheat processors, and the public by working on all aspects of wheat safety from microbiological to chemical hazards and from the farm to processing to the consumer. Application of these research findings in industry will maintain a high demand for Nebraska wheat.

Outcomes/Impacts

Major goals of the project: (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.

Outcomes

The Nebraska-specific objectives under this project are to address wheat safety from three perspectives: 1) microbiological safety; 2) reduction in free asparagine, a precursor to acrylamide, a toxin; and 3) reduction in total and bioavailable cadmium, a toxic heavy metal. This year we made progress on all objectives.

Microbial safety of wheat and wheat-based products has, in recent years, been of high importance with the increase of outbreaks occurring that are directly related to microbial pathogen contamination of wheat. In this study, saturated steam was applied to wheat kernels spread in layers of differing thicknesses in batch style. The wheat berries were steamed in the sieves until they reached either 85 C or 95 C depending on the desired treatment. For each of the treatments both hard red winter wheat and soft red winter wheat were assessed and treated under the previously explained conditions. The resulting microbial testing indicated that in general the treatment temperature for the thicker wheat layer had less of an effect on the microbial reductions, however, for the thinner layer we see that temperature has a much greater impact on microbial reduction. All treatments eliminated mold to undetectable levels and Escherichia coli was not observed in any of the samples. Addition of a thermal treatment to wheat during the milling process has the potential to reduce the possible contamination of wheat with pathogens, therefore, reducing the amount of recalls and outbreaks due to microbial contamination.

Acrylamide, a known neurotoxin, is produced in thermally processed foods through a Maillard-type reaction between the free amino acid asparagine and reducing sugars like glucose and fructose. Wheat-based foods are the source of more than 1/3 of dietary acrylamide; thus, decreasing free asparagine in wheat-based foods could reduce risk of acrylamide toxicity. We analyzed a panel of historical and modern wheats over two crop years to determine changes in asparagine concentration over time. We found that free asparagine decreased with release year in one crop year, but there was no relationship to release year in the other growing year. This suggests that there is both a genetic and environmental effect on asparagine concentration in wheat. Fortunately, the genetic component is trending toward a decrease in the concentration of this free amino acid, which would contribute to a reduction in dietary acrylamide in wheat-based foods.

The excessive accumulation of Cd in harvested crops grown on high-Cd soils has increased public concerns for food safety. Due to the high consumption of bread wheat (Triticum aestivum L.) per capita, high concentrations of Cd in wheat grain can significantly affect human health. Breeding is a promising way to reduce grain Cd concentration. However, a lack of efficient selection methods impedes breeding for low grain Cd concentration in bread wheat. In this study, a recombinant inbred population segregating for grain Cd concentration was used to assess the efficacy of two selection methods for decreasing grain Cd concentration in bread wheat: a hydroponic selection method used shoot Cd concentration in 2-wk-old seedlings growing in Cd-containing medium, and a marker-based selection method using markers linked to heavy metal transporting P1B-ATPase 3 (HMA3), the gene underlying Cdu1. Both methods effectively selected low-Cd lines. The HMA3-linked marker- based selection was superior to hydroponic selection in terms of both simplicity and response to selection. The HMA3-linked markers explained 20% of the phenotypic variation in grain Cd concentration with an additive effect of 0.014 mg kg−1. The hydroponic selection and marker-based selection may target two different and independent processes controlling grain Cd accumulation, and they had no effect on grain Zn and Fe concentrations. The ALMT1-UPS4 marker associated with Al tolerance was not associated with grain Cd concentration but increased grain Zn and Fe concentrations. The 193-bp allele of the Rht8-associated marker, GWM261, was associated with increased grain Cd concentration.

3 PhD students received partial training using funding from this project.

Future Outcomes/Impacts

Next year we plan to intiate projects under all objectives. Specifically, we plan to acquire a steam generator to enable us to determine the effecacy of steam treatment of wheat kernels to reduce microbial load in flour. Next, we plan to determine the role of asparaginase at reducing acrylamide formation in whole grain breads. Finally, we will determine the chemical consitituents in cereal grains that bind cadmium and reduce bioaccessibility.

Publications

Liu, C., M. J. Guttieri, B. M. Waters, K. M Eskridge, and P. S. Baenziger. 2019. Selection of bread wheat for low grain cadmium concentration at the seedling stage using hydroponics versus molecular makers. Crop Sci. 59: 945-956.

Title

Improving Quality of Hard Red Spring and Durum Wheat.

By

Simsek, Senay - North Dakota State University-Fargo
Manthey, Frank

Outcomes/Impacts

For this research, our target audience was University students, extension and industry professionals. academic researchers, and other stakeholders, Durum wheat producers, durum wheat breeders, durum wheat millers, and pasta processors.

The consumption of wheat contaminated with deoxynivalenol (DON), a highly water-soluble Fusarium mycotoxin, represents a health threat to animals and humans. Dry milling does not destroy or remove DON from the grain but physically separates the bran and germ from the endosperm. Information is limited concerning the effectiveness of wet milling processes in removing DON from contaminated wheat dry milling fractions (farina/semolina, shorts, bran). The aim of this research was to determine the extent of DON removal from these wheat fractions during wet milling using the Martin process.

DON) contaminates cereals, causing a negative economic impact on producers. Wet-milling is a process that separates plant components based on chemistry (starch, gluten, lipid, and fiber), which can result in profitable products for the ingredients market. This research aimed to compare the effectiveness of three laboratory scale wet-milling processes (Martin, medium shear, and high shear) on the extraction and functionality of starch from wheat samples containing DON.

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.

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.

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

<u>Major activities completed / experiments conducted</u>

Hard red spring wheat (HRSW) and durum wheat (DW) samples were selected based on their DON content. The control samples contained no detectable DON, and three samples, each of HRSW and DW, were selected because they contained more than 2 mg/kg of DON). Grain and farina/semolina proximate analysis was conducted using AACCI standard methods. The samples were dry milled using a Brabender Quadramat Jr. roller mill. The traditional Martin wet milling method was applied by modifying AACCI method 38-12.02 using a Perten Instruments Glutomatic. The gluten and starch fractions were separated using the wet milling technique. Mycotoxin analysis was done using GC-ECD according to the method of Tacke and Casper (1996).

Further analysis was done on the starch extracted during wet milling processes. In addition to the Martin wet milling method, two other wet-milling methods were performed according to the moderately sheared dough-water

dispersion (medium shear) and highly sheared flour-water dispersion (high shear). The starch from these three wet milling methods was evaluated for DON content by GC-ECD as previously mentioned. Starch damage and pasting properties were determined according to AACCI approved methods. The starch granule morphology was evaluated by scanning electron microscopy and starch gelatinization was measured with differential scanning calorimetry. Proton nuclear magnetic resonance (1H-NMR) was used to determine changes in changes to the molecular structure of the starch.

Data collected

After wet milling farina and semolina containing 2.76–5.07 mg/kg and 3.53–10.39 mg/kg DON, respectively, gluten extracted from hard red spring wheat (HRSW) contained low levels of DON < 0.60 mg/kg, while gluten extracted from durum wheat (DW) contained no detectable DON. The remainder of DON was found in the water-soluble fraction. After wet milling shorts, DON levels were only detected in the freeze-dried water-soluble fraction. After wet milling the bran fraction, DON was found in isolated starch and destarched bran from HRSW and DW; the highest DON concentration was found in the freeze-dried water-soluble fraction accounting 83% and 88% in HRSW and DW, respectively.

DON concentration in farina (3.0 mg/kg) and semolina (8.8 mg/kg) exceeded the security threshold for human consumption. After wet-milling, DON was not detectable in the starch fraction. Starch produced from the medium shear process, had significantly ($P \leq 0.05$) lower protein contamination while transition temperatures significantly ($P \leq 0.05$) decreased compared to the other two wet-milling procedures. Martin process resulted in the method with the greatest starch damage and significantly ($P \leq 0.05$) different thermal and pasting properties when compared to medium and high shear processes.

Summary statistics and discussion of results

Wet milling was effective in removing or decreasing DON levels from all three dry-milled fractions: farina/semolina, shorts, and bran. After wet milling farina/semolina, an average of 97% and 95% of DON was recovered in the freeze dried water-soluble fraction from HRSW and DW samples, respectively. There was no detectable DON in the starch obtained from farina/semolina wet milling, while gluten extracted from farina contained low levels of DON (<0.60 mg/kg) and gluten extracted from semolina had no detectable DON. Similar results were found for the shorts fraction, where an average of 91% and 93% of DON was recovered in the freeze-dried water-soluble fraction for HRSW and DW, respectively. After bran underwent wet milling, the distribution of DON concentration found in the starch, de-starched bran, and water-soluble fraction was 3%, 7%, and 83% for HRSW samples, and 5%, 1%, and 88% for DW samples, respectively.

The three laboratory scale wet-milling processes were effective for the obtention of starch free of DON. Regardless of the wet-milling method utilized, no changes in the fine structure of starch were detected by 1H NMR spectroscopy. However, depending on the wet-milling process applied, differences were detected regarding the granules' physical damage, as well as the proportion of A and B granules, which impacted the viscous and thermal properties. The starch extracted by the medium shear denoted the least starch damage, lower thermal properties than the commercial wheat starch, as well as pasting properties similar to the commercial wheat starch. Martin process resulted in the method with the highest starch damage and significantly different thermal and pasting properties due to its higher proportion of B granules. Since the tested samples underwent Fusarium late infection, the impact on the mycotoxin free starch was not as detrimental as expected, implying its potential for industrial use. Future research encompasses the evaluation of the wet-milling process to other wheat classes (e.g. soft wheat) that might be infected by Fusarium, as well as the assessment of the obtained products (e.g. starch and gluten) in terms of mycotoxins content and physicochemical properties. In addition, further analysis of the starch obtained by wet-milling in food formulations remains a future research direction.

Key outcomes or other accomplishments realized

The implementation of the wet milling technique could be useful in reducing or eliminating DON from dry milling products, which would allow them to be used in animal and human food.

Wet milling provides a valuable alternative for the use of DON contaminated grain in the industrial production of wheat starch

Experiments were conducted to determine the effect of debranning time on milling extraction and semolina quality. Durum wheat wase debranned for 0, 1, 3 and 5 minutes and milled on a Bühler 202 MLU laboratory mill that was configured with two Miag purifiers. Break release was determined for samples that were debranned for 0, 1, and 3 minutes. Break release was determined as the proportion by weight of broken particles that passed through 1,180 µm sieve (U.S standard sieve #16) for the first break. The amount of flour produced by the first break was determined by weight of particles that passed through a 180 µm sieve (U.S standard sieve #80). Milling rate, semolina extraction and semolina ash content, protein content, starch damage, speck count and color were determined.

Impact. Incorporating debranning in the milling process will improve profitability of durum milling which will benefit the durum miller, durum producer, pasta processing industry and pasta consumers. Profitability in milling depends on mill capacity, semolina extraction from grain and quality of semolina.

Outcomes. Debranning grain increased mill throughput which would allow for shortening or simplifying mill flow. The mill was able to process up to 69% more grain (based on weight) when the grain was debranned. Removing bran allowed the ground stock to pass through the mill quicker. Total and semolina extraction were increased with debranning time when calculated based on milled products of Bühler mill. When extraction was calculated when the weight of material removed during debranning was added, both total and semolina extractions decreased slightly. Debranning improved semolina quality as reflected by decreased ash content, and speck counts without impacting semolina starch damage or protein content and functionality.

The results of this work have been disseminated through publication of peer reviewed journal articles, and oral presentations and poster presentations at international, national and regional scientific meetings.

Future plans

There were no issues or problems during the current reporting period. During the next reporting period we will continue to evaluate hard red spring wheat and durum wheat and their end products in order to address the goals and objectives of this project.

Publications

Full Citation:

Magallanes López, A. M., Manthey, F. A. & Simsek, S. (2019). Wet milling technique applied to deoxynivalenol-contaminated wheat dry-milled fractions. Cereal Chemistry, 96, 487-496. NIFA Support was not acknowledged for this Publication.

Full Citation:

López, A. M. M., Manthey, F. A. & Simsek, S. Wet milling of deoxynivalenol contaminated wheat: Effect on physicochemical properties of starch. Cereal Chemistry. NIFA Support was not acknowledged for this Publication.

Magallanes-López, A. M., Manthey, F. A., and Simsek, S. Poster: Can we remove vomitoxin from wheat by wet milling? In: North Dakota State University Graduate Student Council 3rd Annual Research Symposium. April 2019.

Magallanes-López, A. M., Manthey, F. A., and Simsek, S. Poster: Starch fraction characterization obtained from deoxynivalenol infected wheat. In: ND EPSCoR 2019 State Conference. March 2019.

Magallanes-López, A. M., Manthey, F. A., and Simsek, S. Oral presentation: Is wet milling an alternative for Fusarium infected grain? In: North Dakota State University 35th Annual Plant Sciences Graduate Student Symposium. March 2019.

Magallanes-López, A. M., Manthey, F. A., and Simsek, S. Poster: Does wet milling have an impact on starch and gluten fractions? In: North Dakota State University 3 Minute Thesis Competition and Graduate Student Showcase. February 2019.

Title

Monitoring Stored Grain to Manage Quality.

By

Clairmont Clementson, Post-doctoral Research Associate, Agricultural & Biological Engineering, Purdue University, West Lafayette, Indiana.
Klein E. Ileleji, Professor & Extension Engineer

Outputs

The main approach used for monitoring grain storage condition is the continuous measuring of spatial temperature and moisture content variation within the grain mass. Improvements in temperature sensors provide an accurate and inexpensive way of determining the temperature of the grain mass. Cables that provide the equilibrium moisture content of the grain around RH sensors provide a fairly accurate measurement of grain moisture content. CO2 measurements of the bin headspace or exhaust air from the bin, have been shown to provide an early indicator of grain going out of condition. However, since grain is a good insulator the temperature detected by the thermocouples would only reflect the temperature of grains within the immediate area of the thermocouple. Moisture content measured by cables is also location specific and regions not measured would remain undetected should a hotspot happen to develop in that area. Rising CO2 measurements indicate grain going out of condition but doesn't provide information as to what extent is the spoilage and how much grain mass is affected. The time of the year (summer, fall, winter or spring) also have an effect on how these measurements magnify quality problems in the stored grain.

We monitored the CO2 levels of four corn piles from when they were formed in the winter of 2018 through to when they were picked-up in the spring of 2019. Handheld CO2 monitors were used to routinely measure and track CO2 levels and temperatures from the various exhaust of negative suction fans that cooled and held the tarp of the pile down. The goal of this study was to understand CO2 evolution in piles as affected by aeration, ambient temperature and initial grain moisture, and use the data to inform elevator operators of potential quality problems with respect to the corn going out of condition. CO2 and temperature profiles of the four piles were plotted over time and this was discussed with the elevator personnel to understand its correlation to the quality of grain pick-up at the end of storage.

Outcomes/Impacts

The challenge in correctly interpreting data of temperature, moisture and CO2 profiles of the stored grain bulk is still an issue. Elevator operators and farmers need better data interpretation to help them make good management decisions. This research effort in collaboration with a grain elevator provided operations personnel at the elevator with a better understanding of stored bulk condition as measured by temperature, moisture and CO2. However, work is still ongoing on developing analytical tools for data interpretation.

Funding Sources

Infosys

Publications

Clementson, C. and K.E. Ileleji. 2019. Data analytics for effective stored grain management. 2019 Annual International Meeting, July 7-10, 2019, Boston, MA, USA. ASABE, Paper No. 1901242 (poster session).

Contacts

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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., Texas A&M AgriLife Research
Lee, K.M.
Li, W.
Moore, J.

Outputs

The spectroscopic methods based on surface-enhanced Raman spectroscopy and chemometric techniques have been developed for qualitative and quantitative analysis of selected pesticides (chlorpyrifos and aldicarb) in animal feeds. In this study, pesticide-free animal feeds were spiked at different concentration ranges and extracted using a series of extraction media. Gold nanoparticles (AuNPs) were synthesized using a seed-meditated growth technique and mixed with sample extract for SERS measurement. The collected SERS spectra were further preprocessed using different mathematical treatment methods to minimize the influence of environmental and instrumental changes. Several Raman shift regions clearly showed spectral variations and differences in Raman intensity among pesticides groups at different concentrations, depending on the type of samples. Different chemometric models applied on training and external validation datasets of the selected pesticides exhibited an excellent predictive accuracy and lower prediction errors. The findings and implications from the study indicate that SERS-based spectroscopic methods could be a more rapid and less expensive analytical tool for analysis of pesticides in highly complex animal feed matrices on on-site analysis compared to other standard wet-chemical methods.

A new method was developed and validated to simultaneously determine Deoxynivalenols (DON), Ochratoxin A (OTA) and Zearalenone (ZON) in animal feed. Brief procedure: feed samples are extracted with 84/16 acetonitrile/water, diluted to an appropriate concentration, then analyzed by LC/MS/MS. The target analytes are confirmed by retention time and presence of parent/daughter ions. The improvements of the new method compared to the old methods (the previous multi-mycotoxin methods at OTSC) are: the new method can be used to determine three mycotoxins, DON, OTA and ZON with single shot while the old methods need two shots (one for DON and OTA and the other for ZON); the new method is applicable for twelve animal feed matrices while the old methods at OTSC is only limited to corn and cottonseed matrices.

Physical properties of fuzzy cottonseed were used to separate contaminated/moldy samples from clean samples. These properties included color, sphericity, projected area, mass, surface area, volume and density. Samples of cottonseed were contaminated with Aflatoxin B1 and stored for 21 days at 25°C and 85%RH before measuring physical properties, these results were compared to a control sample that had not been inoculated but stored under the same conditions. The findings showed that surface area, density and diameter are used as good indicators of the presence of fungal species and density is a good indicator of the presence of aflatoxins. Color analysis was also performed and L values below 25 indicate microbial infestation in the sample. These results will be used together as a model for determining microbial contamination in fuzzy cottonseed.

To support a global aflatoxin proficiency testing program, a need existed to develop reference material. As per ISO 17034:2016, the reference material provider (RMP) shall assess, by experimentation if necessary, the stability of all relevant properties of an RM under proposed storage conditions and choose pre-treatment, packaging and storage conditions in accordance with the results of the assessment. The effect of repeated subsampling, package type, and

storage time on the stability of the RM was investigated, and an expiration date established. A single level of aflatoxin reference material is currently being assessed for stability at room temperature (20-25°C), refrigeration (0-4°C), and freezer temperature (less than -18°C) using the Stability Worksheet created for Reference Material Production. This worksheet determines stability using analytical results from 5 randomly pulled samples from a RM production lot and comparing the mean and standard deviation to the assigned value from homogeneity. The aflatoxin stability study was started with materials created June 26, 2018. Nine time periods have been completed (43 days, 79 days, 107 days, 147 days, 179 days, 242 days, 324 days, 433 days, and 507 days). There is enough remaining material from the study to run a Time 10 (planned for late February 2020). As of 507 days, materials have remained stable regardless of storage temperature.

An economic analysis of the Texas State Chemist one sample strategy (OSS) was performed using an income statement format comparing 2010 and 2018 economic losses associated with aflatoxin. The OSS has been documented to improve testing accuracy in Texas and Kenya as reported by Sasser in 2018 and Herrman in 2019, respectively. The total economic value of the OSS in 2018 was $14,572,180 for participating firms in Texas.

Outcomes/Impacts

SERS–based spectroscopic methods would be a highly applicable alternative method for qualitative and quantitative analysis of antimicrobials and pesticides in a wide range of feed and food matrices because they are rapid, simple, and cost-effective. The proposed spectroscopic methods and their further improved versions in future could certainly serve as a more effective and powerful analytical tool for well management and control of contaminated feed and food samples to help improve the safety of the products supplied to animals and humans.

The improved multi-toxin analysis method will expand regulatory oversight to a broader matrix of feeds. The increased data will provide greater legal certainty to the feed industry, improve food safety, and help populate the dataset needed to establish action levels for all mycotoxins currently classed as advisory levels, guidance levels, levels of concern or other designation which causes confusion within the regulated community.

The economic benefit of shared governance to manage aflatoxin risk using the one sample strategy should help spur adoption of this form of co-regulation within the Texas grain and feed industry and serves as a useful guide for African, Asian and Latin American countries seeking to manage aflatoxin risk. The study supports the application of regulatory science to the management of risk in regulated products and offers evidence that new approaches to regulating toxin and potentially other hazards can improve profitability while protecting consumers and the market. The OSS is a preventive approach to manage food safety risk in an industry that is currently not regulated under the Food and Drug Administration’s Food Safety Modernization Act.

New techniques to measure and manage aflatoxin in cottonseed and development of stable reference material in corn to support a global aflatoxin proficiency testing program and implement a laboratory quality systems approach in the regulated, regulatory, and academic community will help advance the control of this group I carcinogen.

Publications

Evans, C., and Moore, J. 2019. Differences in physical properties of non-inoculated and aflatoxin inoculated fizzy cottonseeds. 2019 ASABE Annual International Meeting 1900822. (doi:10.13031/aim.201900822)

Hoffmann, V., Grace Randolph, D., Lindahl, J., Mutua, F., Ortega-Beltran, A., Bandyopadhyay, R., Mutegi, C., and Herrman. T. 2019. Technologies and strategies for aflatoxin control in African: A synthesis of emerging evidence.

Herrman, T., and Muiruri., A. 2019. Aflatoxin proficiency testing and control in Africa. IN: Catalyzing the use of aflatoxin control technologies in Kenya and Ghana hosted on the Nairobi campus of the Internationall ivestock Research Institute. https://www.dropbox.com/sh/67fmkb4dhkbgrzx/AAAPT77nA8CrhDEmKd66o2zda?dl=0.

Title

Single Seed N.I.R.S. Measurement for Plant Breeding.

By

Armstrong, Paul R, USDA-ARS, CGAHR, Stored Product and Animal Health Research Unit, Manhattan KS

Outputs

Research resulted in manuscript submission on 1) single-kernel near infrared sorting of maize haploid kernels based on oil content and 2) the determining protein, weight, and oil content in pea (Pisum sativum) for selection of seed quality and yield traits.

Outcomes/Impacts

1) Doubled haploids have become an important breeding tool for creating maize inbred lines. However, several bottlenecks in the doubled haploid 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 in a haploid induction cross, which introduces several constraints on doubled haploid production. Automated sorting based on the chemical composition of the kernel can be effective, but proposed devices have not achieved the necessary sorting speed to be a cost-effective replacement to manual sorting. We evaluated the ability of a single kernel near-infrared reflectance spectroscopy (skNIR) platform to identify haploid kernels. The skNIR platform is a high-throughput device that acquires a NIR spectrum and weight from each kernel. We used skNIR data from 15 haploid induction crosses to construct general discrimination models based on all induction crosses and specific models that only considered kernels within an induction cross. Specific models outperformed the general model and were able to enrich a haploid selection pool to above 50% haploids.

2) Pea (Pisum sativum) seeds are valued for high protein content. Ninety-six diverse pea accessions were used to determine the accuracy of single-seed near-infrared reflectance spectroscopy (NIRS) for predicting pea seed weight, protein, and oil content. External validation of Partial Least Squares (PLS) regression models showed high prediction accuracy for protein and weight ($R2 = 0.94$ for both) and less accuracy for oil ($R2 = 0.75$). The single-seed NIRS protein prediction model was used to determine the impact of seed treatments and foliar fungicides on protein content of harvested dry peas in a conventional field trial. The single-seed NIRS protein values were within 1% of the analytical reference measurement and were sufficiently precise to detect small treatment effects. The study shows that single-seed NIRS could be used to select high protein, high weight peas early in the breeding cycle allowing for faster genetic advancement of pea nutritional quality.

Funding Sources

USDA NP 306 Product Quality and New Uses: Project 3020-43440-008-00D Impacting Quality through Preservation, Enhancement, and Measurement of Grain and Plant Traits

Publications

Armstrong, Paul, Elizabeth Maghirang, Mehmet Ozulu,. 2019. Determining damage levels in wheat caused by Sunn pest (Eurygaster integriceps) using visible and near-infrared spectroscopy. Journal of Cereal Science 86 (2019) 102–107 https://doi.org/10.1016/j.jcs.2019.02.003

Antony R. M., M. B. Kirkham, T. C. Todd, S. R. Bean, J. D. Wilson, P. R. Armstrong, E. Maghirang, and D. L. Brabec. 2019. Low-temperature tolerance of maize and sorghum seedlings grown under the same environmental conditions. J. Crop Improv. 33:287-305.

Casada, M. E., S. A. Thompson, P. R. Armstrong, S. G. McNeill, R. G. Maghirang, M. D. Montross, and A. P. Turner. 2019. Forces on monitoring cables during grain bin filling and emptying. Appl. Eng. Agric. 35:409-415.

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

Collaboration with grain producers, processors and allied scientist and engineers, to generate science-based knowledge to inform improved processing and post-harvest systems' engineering, chiefly for rice, soybean and corn, to maintain the grain quality and mitigate contamination with toxigenic fungi or associated mycotoxins.

Advanced engineering, management and optimization of on-farm, in-bin drying, chilling, storage and aeration processes for the high quality and safety of grains.

Kinetics of grain quality degradation, mold growth, and mycotoxin development during on-farm, in-bin drying, storage and aeration.

Process modelling: accurate mathematical models, their validation and optimization for use in actual grain drying, storage and aeration processes.

Novel techniques to enhance drying rates while maintaining grain quality.

Methods for detection, decontamination, and detoxification of harmful-grain molds and mycotoxins.

Grain and grain processing by-product value addition and utilization.

Outcome/Impacts

A computer simulation platform capable of predicting natural air in-bin drying of rice, corn and soybean has been built; models used in the simulations have been validated using field experiments. Sensors using mathematical equations generated have been developed and are applied in managing grain moisture content by nearly 100 growers in Arkansas and elsewhere.

Provided new recommendations for rice harvesting moisture content. Some 15 million bushels of rice stored in on-farm bins in Arkansas, Louisiana, and Mississippi use recommendations generated for rice harvest moisture content and management strategies to eliminate discoloration during in-bin grain drying and storage.

Recommended rice chilling technology and protocol has been adopted by at least 3 rice growers in Arkansas (for the first time) with significant improvement of milling yield.

Developed innovative one-pass rice drying technology using microwaves. USDA NIFA-Small Business Innovation Grant in collaboration with US industry (Phase 1) is underway. Phase II grant project to support moving technology towards commercialization is under construction. Results demonstrated the potential to use 915 MHz microwave energy (~600 kJ/kg-grain) coupled with "holding" the grain at warm temperatures to significantly lower the rice

moisture contents (to 14-16%) and maintain head rice yields > 65%. On-going study shows great potential to apply technology for parboiled rice drying.

Demonstrated potential for selective infrared heating to inactivate mycotoxigenic molds responsible for aflatoxin contamination of corn.

Training of next generation grain processing and post-harvest engineers: Advised as thesis/dissertation director 7 Ph.D., 2 M.S., and 1 undergraduate honors students; currently on 5 M.S., and 4 Ph.D. graduate student committees.

Publications [* Indicates corresponding author; underline indicates student advisee.]

Refereed Journal Papers.

Shafiekhani S, Lee JA, Atungulu GG*. 2019. Predication of rice milling yield and quality attributes during storage using regression analyses. Transactions of the ASABE, 62(5), 1259-1268. https://doi.org/10.13031/trans.13441.

Shafiekhani S, Lee JA, Atungulu GG*. 2019. Predication of rice milling yield and quality attributes during storage using regression analyses. Transactions of the ASABE, 62(5), 1259-1268. https://doi.org/10.13031/trans.13441.

Bowie RL, Atungulu GG*, Oduola A, Wilson S, Mohammadi-Shad Z. 2019. Impact of Selected Infrared Wavelengths on Inactivation of Microbes on Rough Rice. Discovery, The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences, 20(1), 13-20.

Mohammadi Shad Z, Steen E, Devlieghere F, Mauromoustakos A, Atungulu, G.G*. 2019. Biochemical changes associated with electron beam irradiation of rice and links to kernel discoloration during storage. Cereal Chemistry, 96(5), 824-835. doi: 10.1002/cche.10183.

Mohammadi Shad Z, Atungulu GG*. 2019. Post-harvest kernel discoloration and fungi activity in long-grain hybrid, pureline and medium-grain rice cultivars as influenced by storage environment and antifungal treatment. Journal of Stored Products Research, 81, 91-99.

Mohammadi Shad Z, Ghavami M, Atungulu GG*. 2019. Occurrence of Aflatoxin in Dairy Cow Feed Ingredients and Total Mixed Ration. Applied Engineering in Agriculture, 35(5), 679-686.

Bruce RM, Atungulu, GG*, Sadaka S. Impacts of size fractionation, commingling, and drying temperature on physical and pasting properties of broken rice kernels. Cereal Chemistry, 2019; 00:1–14.

Bruce RM, Atungulu GG*, Hettiarachchy NS, Horax R. 2019. Functional Properties of Endosperm Protein from Size Fractionated Broken Rice Kernels Generated After Milling of Parboiled and Non-Parboiled Rice. Cereal Chemistry, 96(3), 590-604.

Mohammadi Shad Z, Steen E, Atungulu GG*. 2019. Multivariate analysis of rice discoloration and biochemical changes associated with rice storage. Published by the American Society of Agricultural and Biological Engineers, St. Joseph, Michigan www.asabe.org. 2019 ASABE Annual International Meeting 1900095. (doi:10.13031/aim.201900095.)

Atungulu G*. 2019. Microwave drying could improve head rice yields. Published by the American Society of Agricultural and Biological Engineers, St. Joseph, Michigan www.asabe.org. Resource Magazine. 26(6): 24-25.

Book Chapters.

Atungulu GG*, Mohammadi Shad Z. 2019. Reference on Mycotoxins Occurrence, Prevalence, and Risk Assessment in Food Systems. In P. Gaspar, & P. da Silva (Eds.), Novel Technologies and Systems for Food Preservation (pp. 294-343). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-7894-9.ch012.

Atungulu GG*, Shafiekhani S. (2019). Reference on Rice Quality and Safety. In P. Gaspar, & P. da Silva (Eds.), Novel Technologies and Systems for Food Preservation (pp. 226-274). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-7894-9.ch010.

Atungulu GG*, Shafiekhani S. Rice Drying Systems. In. Storage of Grains and Their Products 5th Edition (Eds. Rosentrater, Kurt A). Elsevier Publishers (In Press).

Title

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

By

Ryu, D., University of Idaho

Summary

The Multistate program has provided wheat growers and the grain industry in the Inland Pacific Northwest with a science-based forecast of disease pressure and mycotoxin concerns under climate variability by systematic approach based on fungal population in soil and predicted climate models.

Situation

Deoxynivalenol (DON), known as “vomitoxin”, is a mycotoxin which can contaminate wheat and causes economic losses for growers and food safety concern to consumers. Wheat grains become contaminated with DON after suffering an infection by toxigenic *Fusarium* species which causes a disease known as *Fusarium* Head Blight (FHB). In the Midwestern region of the United States where the majority of wheat is grown the period of maximum rainfall occurs in the spring. Humid conditions during flowering increase the risk of fungal infection and subsequent DON contamination. In the Inland Pacific Northwest (INW) region of the United States the period of maximum rainfall occurs during the winter. The typically dry conditions during flowering in this region makes the occurrence of FHB rare. However, the climate conditions of the INW are forecasted to change in the next century, and it remains unknown if the INW will continue to produce high quality grains free of mycotoxins such as DON.

Response

F. culmorum in agricultural soils by assigning an exponential likelihood distribution to observed population density measurements collected over a two-year soil survey across the INW. Rate parameters for were first estimated using a multilevel model with varying intercepts for each unique field and sampling iteration in the dataset. The posterior distributions of rate parameters were reflective of the uncertainty in the observed measurements.

Taking inspiration from frequency analysis in hydrology, the estimated rate parameters can be utilized in calculating exceedance curves for the population density of *F. culmorum* within an agricultural field. Reporting population densities as a frequency of exceedance provides a more interpretable means of communicating uncertainty to growers. The proportion of a field which is in excess of a given threshold population density can be utilized when making management decisions. The proportion estimates can be applied to any sized field due to the memorylessness of the exponential distribution. We provide a case study that can be adapted for use with other plant pathogens which are highly aggregated in agricultural soil.

Differences in population densities of *F. culmorum* were greater across fields than across sampling iterations. Fields with higher population densities also had greater uncertainty in their posterior median. Fields with higher population densities tended to be from locations with greater annual rainfall and less annual potential evapotranspiration.

We constructed a weather-based proxy for daily soil moisture using a moving sum of total precipitation minus total potential evapotranspiration 90 days prior to sampling (AWB). This moving sum is reflective of seasonal variations in soil moisture content and was used as a predictor variable in a multilevel model. Varying intercept and slope parameters for each field was used to investigate differences in seasonal fluctuations of *F. culmorum* population

densities. Some fields exhibited strong seasonal fluctuations while others remained relatively constant at the average level estimated by the unique intercept. Differences in the effect of AWB across fields is indicative of additional agronomic factors influencing seasonal fluctuations of *F. culmorum*.

We demonstrated the ability to use downscaled daily climate data from global climate models as model inputs to forecast changes in population density under climate change.
Forecasts are specific to each field based on their derived parameters in the multilevel model with varying intercepts and effects. The forecasts suggest that population densities of *F. culmorum* would both remain constant during the winter and spring and decrease during the summer and fall relative to the historical baseline. The varying effects model only accounts for seasonal variation using a weather proxy for soil moisture and soil survey data collected over 2 years.

More studies are needed to better elucidate how populations of fungal plant pathogens may shift under a changing climate in addition to elucidation of how agronomic practices can influence the direction and magnitude of their seasonal fluctuations. The climate model provided herein may provide scaffolding for future modelling efforts to incorporate additional agronomic information using additional parameters.

Outcomes/Impacts

• Formed a network of wheat producers across the Inland Pacific Northwest to collect soil samples for quantification of potentially toxigenic *Fusarium* spp.
• Monitored the population density of *F. culmorum* across a precipitation gradient over 2 years and collected potentially toxigenic isolates for further study
• Evaluated differences in the variability of *F. culmorum* isolation frequency to show that the greatest differences were across fields as opposed to within fields
• Evaluated the limitations of annual climate variables with isolate frequency data to develop a novel approach to quantify *F. culmorum* population densities
• Related the population density of *F. culmorum* to site-specific climate variables to create a predictive model based on precipitation and potential evapotranspiration
• Applied an ensemble of global climate models to forecast future changes in *F. culmorum* population density in the Inland Pacific Northwest under climate change

Publications

Probabilistic forecasts of *Fusarium culmorum* populations in agricultural soil across the Inland Pacific Northwest under climate change. Phytopathology (in review).

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

We have made significant progress on defining skewed distribution of mycotoxins in single corn kernels from commercial samples of Texas corn, developing candidate sorting methods with novel spectroscopy tools, and collect current information on this field in a review paper. An abstract from our most recent poster summarizes this laboratory work.

While the distribution of mycotoxin contamination in bulk corn is known to have skewness there is relatively little data on the distribution of mycotoxins in the single kernels that make up a bulk sample, particularly in commercial samples. Knowledge of single-kernel mycotoxin distribution may explain inaccuracies in bulk-testing and is important for developing single-kernel management strategies such as sorting.

Our purpose was to analyze concentration of aflatoxin and fumonisin in single corn kernels from commercial samples with different bulk levels of contamination.

We obtained 250g samples of commercial corn from Texas previously tested from bulk aflatoxin and fumonisin by the Office of the Texas State Chemist. Samples were stratified by 3 levels (Low, Medium, High) of bulk aflatoxin and fumonisin: Low (<20ppb aflatoxin, <1000ppb fumonisin), Medium (20-50ppb aflatoxin, 1000-4000ppb fumonisin), and High (>50ppb aflatoxin, >4000ppb fumonisin). This resulted in 9 strata for all toxin concentration pairs. From each strata one bulk sample was selected at random and 96 individual kernels picked for a total of 864 kernels. Aflatoxin and fumonisin ELISA kits were used to measure mycotoxins in single kernels. Kernels were considered contaminated at >20ppb aflatoxin or >1000ppb fumonisin (FDA regulatory limits).

Among the 864 corn kernels, only 7 kernels tested >20ppb aflatoxin and 39 kernels tested >1000ppb fumonisin. Comparing contaminated single-kernels to bulk mycotoxin levels, 6 aflatoxin kernels were from bulk samples with HighAF/HighFM and 1 from HighAF/LowFM. For fumonisin contaminated kernels, 12 kernels fell in HighAF/HighFM, 4 kernels in HighAF/MediumFM, 16 kernels in HighAF/LowFM, 4 kernels in MediumAF/HighFM, 3 kernels in MediumAF/MediumFM, and 3 kernels in LowAF/MediumFM bulk level.

The data shows that the distribution of aflatoxin and fumonisin in single kernels is highly skewed even among contaminated commercial corn with different bulk levels

Outcomes/Impacts

A major impact of this work in the last year was a further the education of an MS student Ruben Chavez. Based on this MS work on Texas corn he applied for, and received a 2-year fellowship from the ADM Institute for the Prevention of Postharvest Loss to apply these tools internationally. Our group is now working with existing networks in Ghana to design a study to bring these single kernels tools to that country. In addition, the fellowship allowed Ruben to transfer to the PhD program.

Publications

Cheng, X., A. Vella, and M. J. Stasiewicz. 2019. Classification of aflatoxin contaminated single corn kernels by ultraviolet to near infrared spectroscopy. Food Control. 98:253-261.

Funding Source(s) and Amount(s)

This mycotoxin study was supported by a departmental Lo Fellowship and USDA Cooperative State Research, Education, and Extension Service Hatch Project ILLU-698-903.

Ph.D. Student Ruben Chavez has received a Postharvest Loss Prevention Graduate Assistantship from the ADM Institute for the Prevention of Postharvest Loss. 2 years support to study multi-spectral sorting to reduce mycotoxins in maize.

Title

Methods and Guidelines for Enabling Traceability in the Bulk Product Supply Chain.

By

Bowers, Erin, Associate Scientist, Agricultural & Biosystems Engineering, Iowa State University
Hurburgh, Charles, Professor, Agricultural & Biosystems Engineering
Maier, Dirk, Professor, Agricultural & Biosystems Engineering
Mosher, Gretchen, Associate Professor, Agricultural & Biosystems Engineering

Outputs

Several tools were developed to enhance guidance on traceability methods as used in the bulk product supply chain. A template approach was used to develop guidance documents to facilitate traceability objectives throughout the grain supply chain. A terminology glossary of terms related to grain traceability was developed to create standardized understanding among grain traceability stakeholders. A system design modeling approach was used to simplify multiple networks in the soybean supply chain, identifying critical traceability events and key data elements for achieving specific traceability objectives.

Risk management tools were applied to identify grain supply chain options that are most responsible for failures in a segmented marketing system. The case studied is that of non-GM ingredients in animal feed. The underlying question concerns the impact of a progressively increasing demand for non-GM livestock feed on U.S. grain and feed industry supply chain operations.

Outcomes/Impacts

A methodological traceability template provides a starting point for regulatory and business-based traceability in the bulk grain supply chain. Complexities associated with interlinked operations across supply chain participants have been one obstacle to effective traceability for bulk materials in the past. These documents will provide more concrete methods and guidelines for enabling traceability in the bulk grain supply chain.

Publications

Sharma, Richa. 2019. Development of a standards-based traceability system for the U.S. grain and feed supply chain. Doctoral dissertation.

Sharma, R., C.R. Hurburgh, G.A. Mosher. Developing methods, guidelines, best practices, and terminology supporting multiple traceability objectives in the grain supply chain. Manuscript to be submitted to Cereal Chemistry.

Sharma, R. C.R. Hurburgh, G.A. Mosher. Modeling a traceability system for the soybean supply chain using critical traceability events and key data elements in ArgoUML. Manuscript to be submitted to Comprehensive Reviews in Food Science and Food Safety Journal.

Sharma, R., C.R. Hurburgh, G.A. Mosher. Vulnerability analysis using evidence-based traceability in the grain supply chain. Manuscript to be submitted to Comprehensive Reviews in Food Science and Food Safety Journal.

Funding Sources

National Institute of Standards and Technology (NIST)

Title

Role of Worker Decision-Making in Effective Food Safety Modernization Act Implementation.

By

Bowers, Erin, Associate Scientist, Agricultural & Biosystems Engineering, Iowa State University
Mosher, Gretchen, Associate Professor, Agricultural & Biosystems Engineering

Outputs

Several food safety decision-making scenarios have been developed for use with personnel who have completed the Preventive Controls Qualified Individual training for animal foods. The primary goal of the project is to better understand the decision-making process of those make decisions about food safety in the grain and feed handling environment. Scenario instruments were finalized in the summer and early fall of 2019 in preparation data collection in winter 2020.

Outcomes/Impacts

A better understanding of the decision-making process has potential to improve training and professional development of employees. Long term, the goal is to increase the number of grain feed industry employees who can make appropriate food safety decisions relating grain and feed product handling.

Publications

E. Bowers and G.A. Mosher. 2019. Role of worker decision making in effective Food Safety Modernization Act implementation. Presentation given at the North Central (NC) 213 Quality Grains Research Consortium. Ames, IA.

Funding Sources

The Andersons Research Grant Program – Regular Competition 2017

Title

Segregation Strategies for non-GM corn: Improving Effectiveness Through an Analytical Modeling Approach.

By

Dolphin, Chad J., Graduate Research Assistant, Iowa State University
Mosher, Gretchen A., Associate Professor

Salish, Karthik, Graduate Research Assistant, Purdue University
Ambrose, R.P. Kingsly, Associate Professor

Outputs:

A software tool was developed to predict the probability distribution of genetically modified (GM) contamination in non-GM grain lots using user inputs such as final quantity of processed corn, overall tolerance level, and moisture content. The output from the software includes the mass of corn in each processing stage, the tolerance level and the probability distribution of potential GM contamination.

In the second component of this project, Monte Carlo simulation was used to test nine growing/handling scenarios to determine the feasibility of successfully meeting three tolerance levels for adventitious presence (0.9%, 1.5%, and 3.0%). Adventitious presence measures the level of genetically modified (GM) grain in a load that is sold as non-GM. Variables tested included: field isolation distance, elevator handling practices, equipment residue, and seed purity. 50,000 iterations were completed for each simulation model.

Outcomes/Impacts:

The software developed predicted the probability of contamination with adventitious presence at tolerance levels of 5.0%, 3.0%, 1.0%, 0.9%, 0.5%, and 0.1% as 0.05, 0.07, 0.11, 0.12, 0.16, and 0.36, respectively. The mean absolute percentage error for the predictions was found to be 3.07%. The software can be used as a tool in testing for GM contamination in non-GM grain against a desired threshold levels in a grain handling environment.

Results for the Monte Carlo simulation suggest that non-GM loads would not meet a tolerance level of 0.9% in most cases. Non-GM corn loads were found to meet tolerance levels of 1.5% and 3.0% in certain cases. The most significant factors affecting the probability of meeting the tolerance level were field isolation distances, elevator handling practices, and seed purity. Seed purity is the most difficult of these to control and manage. Implications of the research suggest that seed purity has the potential to push adventitious presence over the tolerance level in some cases.

This project provides tools for prediction and decision-making about feasible tolerance levels by providing data to support the long-standing question about the feasibility of existing tolerance levels. In the short term, the data will assist policy makers as they set GM policy and tolerance levels for international markets. In the long term, the data and tools generated by the project will lower the risk level for non-GM growers, breeders, and handlers.

Publications

Salish, K., G.A. Mosher, and R.P.K. Ambrose. Developing a graphical user interface (GUI) to predict the contamination of GM corn in non-GM corn. Under review by Applied Engineering in Agriculture (accepted December 2019).

Dolphin, C.J. 2019. Segregation strategies for non-GM corn: Improving effectiveness through a structured modeling approach. Master's thesis.

Dolphin, C.J., R.P.K. Ambrose, and G.A. Mosher. 2019. Segregation strategies for non-GM corn: Improving effectiveness through an analytical modeling approach. Presentation given at the North Central (NC) 213 Quality Grains Research Consortium. Ames, IA.

Dolphin, C.J. and G.A. Mosher. 2019. Modeling the feasibility of existing tolerance levels for non-GM corn. Poster presented at the ASABE Annual International Meeting, Boston, MA.

Dolphin, C.J., G.A. Mosher, R.P.K. Ambrose, and S.J. Ryan. Probabilistic modeling to determine the feasibility of success in the segregation of non-genetically modified corn. Manuscript to be submitted to Applied Engineering in Agriculture.

Funding Sources

The Andersons Research Grant Program – Team Competition 2016

Title

A Risk Management Approach for Effective Segregation of GM and non-GM Grain in Feed Supply Chain.

By

Priyanka Gupta, Graduate Research Assistant, Iowa State University
Charles R. Hurburgh, Professor
Erin Bowers, Adjunct Assistant Professor
Gretchen Mosher, Associate Professor

Outputs

Increased production of genetically modified (GM) crops has led to an elevated risk of adventitious presence of GM grain in non-GM feed supply chains. In non-GM markets, detection of genetically modified content in feed above a threshold level can lead to extreme market losses. The question of concern is how to manage the risk of GM adventitious presence in non-GM feed supply chain. Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) are the two risk management tools proposed in this study for managing the risk of commingling. The first part of the study uses FMEA to analyze the physical flow of grain in a feed supply chain, with the aim of identifying processes leading to unintentional commingling and their associated risk factors. In second part of the study, FTA is used to identify the different combinations of events that can lead to unintentional commingling. In total, the study provides empirical insights into the management of adventitious presence in the feed supply chain and expands the domain of risk assessment and management in feed processing sector. The results of FMEA and FTA show the critical risk factors for adventitious presence, its causes, effects, and management strategies.

Outcomes/Impacts

Increasing consumer interest in animal products fed nonGM 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. This is one segment of a study to estimate the overall percentage of NonGM ingredient that could create significant overall cost increases and hardships for the US feed sector.

Funding Sources

American Feed Industry Association

Contacts

Priyanka Gupta, Graduate Research Assistant, gupta@iastate.edu

Title

Identification and Testing of Physical Parameters to Quantify the Behavior of Grain Flow for Traceability Purposes.

By

Hurburgh, Charles, Professor, Agricultural & Biosystems Engineering, Iowa State University
Mosher, Gretchen, Associate Professor
Tenboer, Heather, Graduate Research Assistant

Outputs

To accommodate the blended and comingled nature of bulk materials, a mathematical characterization and model the flow of grain and bulk materials at points across the grain and grain product supply chains allows researchers to predict how inputs will distribute in the blended load. This research investigated First in First out (FIFO) and Last in First out (LIFO) flow patterns to determine the sequence of grain flow out of a flat-floor cylindrical bin. 10 trials of three experiments were performed. Two stable outputs were observed: core flow behavior and a consistent pattern of flow behavior

Outcomes/Impacts

The results of the work will facilitate the use of probability models to characterize the traits and components of a given shipment of grain. Results will also facilitate improved traceability in the bulk commodity handling environment.

Publications

Tenboer, H.H., G.A. Mosher, and C.R. Hurburgh. 2019. A model of factors influencing grain traceability: A quantification of grain layer mixing in storage facilities. Paper presented at the 2019 ASABE Annual International Meeting, Boston, MA. Paper #1900594.

Tenboer, H.H. 2019. Verification of the use of a model for quantification of granular mixing due to load out from a flat-floored cylindrical steel bin. Master's thesis.

Funding Sources

National Institute of Standards and Technology (NIST)

Title

Wireless Sensors for Quality Monitoring and Management of Stored Grain Inventories.

By

Maier, D.E., Professor, Agricultural & Biosystems Engineering, Iowa State University
Aby, R., Graduate Research Assistant
Brumm, T., Associate Professor
Bern, C., Professor Emeritus

Outputs

Research during the first project year focused on comparing the effectiveness of a new wireless sensor technology against a conventional cable-based sensor system by monitoring temperature and relative humidity in the stored grain mass during aerated and non-aerated periods, determining the vertical and horizontal distribution of the wireless sensors as a result of gravity-filling a storage bin and quantifying the uniformity of sensor distribution and usefulness of data for stored grain quality monitoring in comparison to a cable-based sensor system, and using the 3D MLP ecosystem model to determine the number of wireless sensors needed to achieve sufficient accuracy for stored grain quality monitoring based on the predicted temperature and moisture content values in the grain mass using a cable-based sensor system versus wireless sensors as a function of different bin sizes and predicted sensor distribution.

Results indicate that 11 out of 14 wireless sensors were statistically the same as the cable-based sensors with respect to measuring both temperature and relative humidity values. For the three sensors that were not the same with respect to relative humidity, the average relative humidity of the wireless sensors was 4 percentage points lower compared to the average relative humidity of the cable sensors. A 4 percentage point difference in relative humidity is not considered substantially different because it only affects the grain moisture content by ± 0.2 percentage points. Therefore, relative humidity sensors off by 4 percentage points or less would be considered sufficiently accurate for reliably monitoring and managing stored grain quality.

Due to the slinging of the wireless sensors by the grain distributor towards the wall during filling of the grain bin in 2017, it was not possible to get useful results about vertical and horizontal placement of the sensors in the grain mass. Instead, results focused on recovery of the 44 wireless sensors that were in the stored grain mass during unloading of the bin. The same was true for an additional three trials with 15, 20 and 25 wireless sensors placed in the grain mass. During unloading of the stored corn, 100% of the wireless sensors were recaptured. In 2019 the distribution of both spherical- and square-shaped wireless sensors of different sizes was investigated in a stored grain bin that was loaded with a portable conveyor. The results indicated that the square-shaped wireless sensors tended to settle near the center of the grain pile whereas the spherical-shaped wireless sensors tended to settle closer to the bin wall. Therefore, sensor shape and size need to be considered to achieve the desired distribution of wireless sensor distribution within a stored grain mass when loading a bin with gravity flow.

In terms of the effect of sensor numbers and their distribution, the MLP 3D ecosystem model was used to investigate placement and position of sensors, and the effects of these variables on operating aeration systems and maintaining stored grain quality. Several preliminary simulations were conducted. A set of simulations was conducted with randomized sensor locations. The average temperature values were similar, but a greater number of sensors reduced year to year variability.

Outcomes/Impacts

Therefore, the use of wireless sensors has great potential as long as they can be placed in a pattern throughout the grain mass that is sufficiently representative to allow an automated monitoring and fan control system to maintain stored grain quality according to the goals set by the stored grain manager.

Publications

Aby, R.G., Maier, D.E. 2019. Wireless sensors for quality monitoring and management of stored grain inventories. NC-213 Annual Meeting and Technical Conference. Ames, Iowa, February 26-27, 2019.

Aby, R.G., Maier, D.E. 2019. Wireless sensors for quality monitoring and management of stored grain inventories. ASABE Annual International Meeting. Boston, Massachusetts, July 7-10, 2019.

Aby, R.G., Maier, D.E. 2019. Wireless sensors for quality monitoring and management of stored grain inventories. 2nd All Africa Post-Harvest Conference and Exhibition. Addis Abba, Ethiopia, September 17-20, 2019.

Aby, R.G. 2019. Wireless sensors for quality monitoring and management of stored grain inventories. Norman Borlaug Poster Competition. Ames, Iowa, October 14, 2019.

Funding Sources

The Andersons Research Grant Program – 2018

Title

Marketing and Delivery of Quality Grains and BioProcess Coproducts.

By

Kaliramesh Siliveru, Kansas State University
Subramanyam Bhadriraju
Thomas Phillips,
Carlos Campabadal

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.

Resistance to the fumigant phosphine in Tribolium castaneum occurs worldwide. This year study evaluated tests based on adult knockdown time, the time for a beetle to become immobile, when exposed to a high concentration of phosphine. We recorded knockdown times of beetles that remained completely still for 30 s when exposed to 3000 ppm of phosphine in a large, gas-tight glass tube. Beetles were used from 12 populations, of which six were 'susceptible' to phosphine, three were 'weakly resistant', and three were 'strongly resistant'. Knockdown times were determined for single beetles, as well as for groups of ten beetles for which the time to knockdown for either five beetles (KT50) or ten beetles (KT100) were recorded. Similar knockdown times occurred across susceptible and resistant populations. However, the KT100 tests generated conservative times for diagnosing strong vs. weak resistance. The strong resistant populations were all over 100 min with KT100, compared to 60 min or less for susceptible and weak resistant populations. Special tests on single beetles revealed higher knockdown times in insects that were deliberately disturbed compared to those without any disturbances. Work reported here suggests a knockdown test conducted on beetles in a matter of minutes or hours could help classify phosphine resistance status prior to decisions on phosphine fumigation.

In this year, we have also developed mathematical models to predict the heat transfer in the DDGS piles. These models will help the ethanol industries to predict the temperatures prior to loading the DDGS into trucks, so that the cake formation in the trucks could be delayed. We have also developed tools to prevent the formation of bridges/cakes during the transportation of wheat flour in the milling industries.

In this year, we have also evaluated the efficacy of Ozone as a potential alternative to control phosphine resistant strains of the lesser grain borer, Rhyzopertha dominica (F.). The efficacy of ozone against one phosphine-susceptible laboratory and two phosphine-resistant field strains of R. dominica was evaluated at two concentrations (0.21 and 0.42 g/m3). We have also evaluated the efficacy of Triplex and filter cake powders from Ethiopia against stored-product insects: Filter cake and Triplex are powdered by-products of aluminum sulfate and soap factories, respectively. The efficacy of filter cake and Triplex against the maize weevil, Sitophilus zeamais, rice weevil, Sitophilus oryzae (Linnaeus); lesser grain borer, Rhizobertha dominica Fabricius; red flour beetle, Tribolium castaneum (Herbst); saw-toothed grain beetle, Oryzaephilus surinamensis (Linnaeus); and Indian meal moth, Plodia interpunctella (Hübner), was determined using a range of concentrations and exposure times. On concrete surfaces ≥ 7.5 g/m2 of filter cake produced more than 99% mortality of S. zeamais and S. oryzae adults within 12-24 h,

whereas more than three times the concentration of filter cake was required to achieve similar mortality of both species in Triplex treatments. At 3 g/m2 of filter cake, 99% mortality S. zeamais and S. oryzae adults was achieved within 22-27 h of exposure. The corresponding exposure time at 9 g/m2 of Triplex was 39 h to achieve 99% mortality of both species. For both powders, lower concentrations and exposure times were required to achieve complete suppression of progeny production, percentage of insect damaged kernels, and percentage of grain weight loss compared to the concentrations and exposure times required for 00% mortality. In this year, we have also evaluated the efficacy of methoprene and spinosad applied to popcorn against immature stages of Plodia interpunctella and Sitophilus zeamais. These results indicated that the persistence and efficacy of methoprene and spinosad lasted for at least six months under field conditions.

Publications

Athanassiou, C. G., T. W. Phillips, and W.Wakil. 2019. Biology and Control of the Khapra Beetle, Trogoderma granarium, a Major Quarantine Threat to Global Food Security. Ann. Rev. Entomol. 64:131–48.

Cato, A., E. Afful, M. K. Nayak and T. W. Phillips. 2019. Evaluation of knockdown bioassay methods to assess phosphine resistance in the red flour beetle, Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae). Insects. 10:140 doi:10.3390/insects10050140

Cordeiro, E. M. G. Campbell, Phillips, Akhuno. 2019. Isolation by distance, source-sink population dynamics and dispersal facilitation by trade routes: impact on population genetic structure of a stored grain pest. G3: Genes|Genomes|Genetics. 9: 1457-1468.

Nayak, M. K., R. Kaur , R. Jagadeesan, H. Pavic, T.W. Phillips and G. J. Daglish. 2019. Development of a quick knock down test for diagnosing resistance to phosphine in rice weevil, Sitophilus oryzae, a major pest of stored product. J. Econ. Entomol. 112: 1975-1982

Cordeiro, E. M. G., J. F. Campbell, and T. Phillips. 2019. Differences in orientation behavior and female attraction by Rhyzopertha dominica (Coleoptera: Bostrichidae) in a homogeneous resource patch. Environ. Entomol. 48: 784-791.

Zhaorigetu H.,·H. Jiang, D. Schlipalius, Y. Park, R. N. C. Guedes, B. Oppert, G. Opit, T. Phillips. 2019. A CAPS marker for determination of strong phosphine resistance in Tribolium castaneum from Brazil, J. Pest Sci. https://doi.org/10.1007/s1034 0-019-01134 -4

Morales-Quiros, A., C. A. Campabadal, D. E. Maier, S. Lazzari, F. Lazzari, S. Cook, T. W. Phillips. 2019. Chilling aeration to control pests and maintain grain quality during in-bin storage of wheat in Kansas. Am. Society Agricul. and Biosystems Engineers Meeting Presentation. Paper Number: 162448464. DOI: 10.13031/aim.20162448464

Ramadan, G. R. M., S. A.M. Abdelgaleil, M. S. Shawir, A. S. El-bakary, P. A. Edde, T. W. Phillips. 2019. Residue analysis of the fumigant pesticide ethanedinitrile in different agricultural commodities using ether extraction and GC-MS. J. Stored Prod. Res. 83: 331-337.

Kalsa K. K., Bh. Subramanyam, G. Dimissie, R. Mahroof, A. Worku, and N. Gabbiye. 2019. Evaluation of postharvest prevention strategies for stored wheat seed in Ethiopia. Journal of Stored Products Research 81: 53-61.

Tadesse, T.M., and Subramanyam, Bh., 2019. Efficacy of filter cake and Triplex powders against three internally developing stored-product insect species. American Journal of Entomology 3: 15-23.

Tadesse, T. M., Bh. Subramanyam, K. Y. Zhu, and J. F. Campbell. 2019. Contact toxicity of filter cake and Triplex powders from Ethiopia against adults of Sitophilus oryzae(Linnaeus) (Coleoptera: Curculionidae). Journal of Stored Products Research 80: 34-40.

Tadesse, T. M., Bh. Subramanyam, K. Y. Zhu, and J. F. Campbell. 2019. Contact toxicity of filter cake and Triplex powders from Ethiopia against adults of Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae). Journal of Economic Entomology 112: 1469-1475.

Tadesse, T. M., and Bh. Subramanyam. 2019. Efficacy of filter cake and Triplex powders from Ethiopia against three externally developing stored product insect species. Journal of Stored Products Research 82: 73-80.

Kalsa, K.K., Subramanyam, Bh., Demissie, G., Mahroof, R., and Gabbiye, N. 2019. Mortality of Sitophilus granarius (L.) and Rhyzopertha dominica (F.) adults exposed to different concentrations of filter cake in stored wheat. Ethiopian Journal of Agricultural Sciences 29: 99-107.

Agrafioti, P., Athanassiou, C.G., and Subramanyam, Bh. 2019. Efficacy of heat treatment on phosphine resistant and susceptible populations of stored product insects. Journal of Stored Products Research 81: 100-106.

Worku, A. F., M. Abera, K. K. Kalsa, Bh. Subramanyam, and N. G. Habtu. 2019. Occurrence of mycotoxins in stored maize in Ethiopia. Ethiopian Journal of Agricultural Sciences 29: 31-43.

Kalsa, K. K., BVh. Subramanyam, G. Demissie, A. F. Worku, and N. G. Habtu. 2019. Major insect pests and their associated losses in quantity and quality of farm-stored wheat seed. Ethiopian Journal of Agricultural Sciences 29: 71-82.

Kalsa, K. K., Bh. Subramanyam, G. Demissie, R. Mahroof, A. Worku, N. Gabbiye, S. Workneh, and F. Abay. 2019. Susceptibility of Ethiopian wheat varieties to granay weevil and rice weevil infestation at optimal and sub-optimal temperatures. Journal of Stored Products Research 83: 267-274.

Xinyi, E., L. Beibei, and Bh. Subramanyam. 2019. Efficacy of ozone against adults and immature stages of phosphine susceptible and phosphine resistant strains of Rhyzopertha dominica. Journal of Stored Products Research 83: 110-116.

Molla, A., S. Alavi, Bh. Subramanyam, S. Workneh, and N. Gabbiye. 2019. Performance comparisons of solar mixed and indirect dryers for maize grain drying, pp. 145-159. ICST Institute for Computer Sciences, Social Informatics, and Telecommunications Engineering 2019. Springer Nature Switzerland A. G. 2019. https://doi.org/10.1007/978-3-030-15357-1-12.

Siliveru, K., M. E. Casada, and R. P. K. Ambrose. 2019. Heat transfer during cooling of bulk low-oil distillers dried grains with solubles (DDGS). Applied Engineering in Agriculture, 35, 569-577.

Title

Measurement of Temperature and Relative Humidity in Bagged Storage.

By

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

Outputs

Monitoring temperature and moisture content during storage is critical for evaluating changes and potential losses in grain quality. Numerous monitoring systems have been proposed, but are not widely used. The proposed system consisted of eight on-board integrated temperature and relative humidity sensors (Sensirion, Model SHT35) connected to a custom Arduino-based data acquisition system. The data acquisition system recorded a time stamp, temperature and relative humidity at a user specified time interval onto a micro SD card.

The sensors were calibrated in an environmental control chamber at 33%, 55% and 75% RH and 10C, 25C and 40C temperature using saturated salt solutions (magnesium chloride, magnesium nitrate and sodium chloride). Temperature readings showed a marginal difference of plus or minus 0.2C for all the sensors. The regression of the measured versus actual indicated a slope of 1. However, the intercept of for the regression between measured RH of the sensors and known humidity points ranged between 3.2% and 4.1% with an average value of 3.7%.

The time for the sensors to reach equilibrium with the air in the interstitial space of the gain bulk was also determined. To evaluate the equilibration time for the sensors, glass jars with corn conditioned to 13.5% was used. Sensors were passed through rubber stoppers into the jars. This was set up in environmental chamber set at 25C and 75% relative humidity. Temperature and relative humidity were recorded at 30 second intervals for 15 minutes. The results indicated an initial rapid progression towards equilibrium within the first 2 minutes. The relative humidity continued on an asymptotic path to equilibrium, with the readings stabilizing after approximately 5 minutes. The average change for temperature was less than 0.05C after 4.5 minutes, while an average change of less than 0.05% was attained for relative humidity after 5.5 minutes. Standard deviation of the eight sensors ranged from 0.31C to 0.44C and 1.44% to 1.84% for T and RH respectively. Similar trends were observed for other storage conditions. It is suggested that the sensors would have reached an equilibrium condition with the grain environment after 5 minutes. Thus, the system will adequately measure T and RH during storage where the conditions change much slower.

Outcomes/Impacts

The focus is on the development of alternative sensor systems for measurement of grain quality during bagged storage. This could include future incorporation into silo bags and monitoring of other bagged commodities.

Title

Mitigating the Separation of Dust from Grain Kernels.

By

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

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

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

Outputs

Grain dust explosions occur when dust accumulates beyond the minimum explosible concentration in a confined space and is exposed to oxygen and an ignition source. High dust concentrations that occur with grain handling operations can cause other serious problems, including health and safety risks from dust inhalation. Facilities that handle grain can be at risk of explosion if dust particles are released during handling producing spaces with sufficient dust concentration for explosion. Workers in the facilities may be at risk from inhaling the dust.

The adhesion force that holds the grain dust particles to the grain itself is an important factor in better understanding grain dust and mitigating the separation of dust from grain kernels. To evaluate adhesion forces, a centrifuge was used to separate the dust from the grain kernels and determine the forces required for separation. There was large variability in dust concentration between the five samples tested. After repeatedly centrifuging the samples, we found there was a subset of the total adhered dust removed at the lowest centrifuge speed (1000 rpm), followed by a second subset with much higher attachment strength that was only removed with centrifugation at 3000 to 4000 rpm. This indicates that a portion of the total grain dust is likely to be detached during any physical handling of corn, but that care should be taken that the impact velocities of grain kernels not grow high enough to release the additional quantities of dust that are more strongly attached.

We also evaluated how dust particles attach to the grain surface and later become dislodged creating dangerous dust clouds. The dust particle shape and structure are factors thought to influence the strength of attachment of the dust to the grain. To better understand these factors, dust samples were analyzed for physical characteristics such as circularity, length to width ratio, surface roughness, attachment strength to corn, and particle size. The freshly harvested corn samples contained more small particles with low circularity than older lower quality samples. The large particles were determined to be starch, while the smaller particles were more likely soil. Dust particles that were more strongly attached to corn kernels had lower surface roughness measurements than those that were weakly attached, although the difference was negligible in some corn samples.

Outcomes/Impacts

These results improve our understanding of how dust particles are removed from corn to cause dust cloud generation and about the relationship of dust particle shape and structure to the release of grain dust to the atmosphere. This information will be valuable for grain handlers and grain elevator operators for evaluating and improving their handling procedures to reduce their safety and health hazards and air pollution problems.

Publications

Plumier, B.M., Zhao, Y., Casada, M.E, Maghirang, R.G., Ambrose, R.P.K. 2020. Dust content and adhesion characteristics of five corn samples. In Press: Transaction of the ASABE.

Funding Source(s) and Amount(s)

USDA-AFRI

Title

Post-harvest Quality and Maintenance of Maize in Ghana

By

Armstrong, Paul R, USDA-ARS, CGAHR, Stored Product and Animal Health Research Unit, Manhattan KS

Outputs

Manuscripts were published on maize moisture content, insect populations and mycotoxin levels in northern Ghanaian farms in the Tamale area. Several common farm practices were examined which included harvest practices, storage methods and drying. Also documented was the effect that storage structures have moisture content, insect populations and mycotoxin levels for the major and minor seasons in the middle belt region of Ghana. Drying to control moisture and disinfest maize of insects was studied using a solar-biomass heated dryer versus traditional solar drying; results were published.

Outcomes/Impacts

Harvest practices which heaped maize into piles before threshing showed increased levels of aflatoxin beyond acceptable limits. Alternative practices to heaping need to be developed to prevent unacceptable aflatoxin development. The solar-biomass dryer was effective to control moisture and to disinfest maize from adult insects as well as provide relatively high drying rates thus providing an effective insect knockdown prior to bagging and storage.

Publications

Manu, N., E. A. Osekre, G. P. Opit, F. H. Arthur, G. Mbata, P. Armstrong, J. K. Danso, S. G. McNeill, and J. Campbell. 2019. Moisture content, insect pests and mycotoxin levels of maize on farms in Tamale environs in the northern region of Ghana. J. Stored Prod. Res. 83:153-160.

Bosomtwe, A., J. K. Danso, E. A. Osekre, G. P. Opit, G. Mbata, P. Armstrong, F.H. Arthur, J. Campbell, N. Manu, S. G. McNeill, and J. O. Akowuah. 2019. Effectiveness of the solar biomass hybrid dryer for drying and disinfestation of maize. J. Stored Prod. Res. 83:66-72.

J.K. Danso, E.A. Osekre, G.P. Opit, F.H. Arthur, *, J.F. Campbell, G. Mbata, N. Manu,
P. Armstrong, S.G. McNeill. 2019. Impact of storage structures on moisture content, insect pests and mycotoxin levels of maize in Ghana. J. Stored Prod. Res. 81:114-120

Funding Sources

USAID Feed the Future Lab for the Reduction of Post-Harvest Loss

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 grain bulk density values for grain grading, designing storage systems, and estimating the mass of grain in bins. Bulk density of grain in a storage bin increases with the overbearing pressure of the grain and varies with handling processes such as grain fall height, filling rate, and use of a spreader as compared to spout filling. The widely varying interactions between kernels under compaction create a complex problem that can best be analyzed in computer models by considering the movement and interactions of each individual particle. This computer modeling technique, called the discrete element method (DEM), requires knowledge of how the particle shape and contact parameters (such as coefficients of friction) affect modeling a system such as this wheat bulk density. To improve the modeling and understanding of grain compaction processes, experimental density measurements and DEM modeling simulations were conducted. Results showed that the bulk density is higher for particles having lower length to width ratio and smoother surfaces, indicating that it is important to capture those aspects of the true shape of particles being modeled to accurately predict grain bulk density. The most important contact parameters for modeling were identified as the particle-to-particle coefficient of static friction and particle-to-particle coefficient of rolling friction. Determining these material properties accurately will improve the prediction of grain bulk density as affected by different handling processes.

DEM modeling of bulk density measurement was also used to evaluate two particle models (single-sphere and five-sphere) for simulating the effect of grain drop height on the bulk densities of two cultivars of hard red winter wheat. The two cultivars have different particle size distributions, which resulted in differences in measured bulk density. DEM simulations of density measurement based on both particle models agreed with experimental results by showing lower simulated bulk density for the correct cultivar based on the differing particle size distribution. The simulations also matched experimental results showing bulk density increasing with higher grain drop heights. The simulation results for the single-sphere particle model were comparable with the five-sphere particle model when calibrated with the contact parameters individually for each size fraction of wheat. The five-sphere particle model was better for simulating the heap profile of wheat observed in the experiments but has a disadvantage of requiring greater computational effort.

Outcomes/Impacts

These results provide a better understanding of the influence of particle shape and contact parameters on simulating bulk density for wheat. In addition, an effective particle model has been defined with three size fractions for use in simulating container filling operations using the DEM method. Also, even though the five-sphere model of wheat kernels better captured the heap profile behavior in the bulk density simulations, use of single-sphere model seems to be more practical in most cases because of lower computational cost. Accuracy of DEM predictions can be improved through individual calibration of contact parameters for each size fraction and considering the size distribution of these size fractions in the model. Models of grain packing based on these particle models and calibration procedures can be used to predict grain packing more accurately based on kernel properties and size fractions present in the grain bulk, which will also provide a better understanding variation in packing factor based on the kernel properties.

Publications

Bhadra, R., M.E. Casada, S.A. Thompson, M.D. Montross, A.P. Turner, S.G. McNeill, R.G. Maghirang, and J.M. Boac. 2018. Stored grain pack factor measurements for soybeans, sorghum, oats, barley, and wheat. Transactions of the ASABE 61(2): 747-757.

Petingco, M.C., M.E. Casada, R.G. Maghirang, S.A. Thompson, S.G. McNeill, M.D. Montross, A.P. Turner. 2018. Influence of kernel shape and size on the packing ratio and compressibility of hard red winter wheat. Transactions of the ASABE 61(4): 1437-1448.

Casada, M.E., S.A. Thompson, P.R. Armstrong, S.G. McNeill, R.G. Maghirang, M.D. Montross, A.P. Turner. 2019. Forces on monitoring cables during grain bin filling and emptying. Applied Engineering in Agriculture 35(3): 409-415.

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

Maximizing Processing Value with Selective Handling Strategies: An Analysis of Soybeans Received at Iowa Elevators.

By

Bennett E Barr, Former Graduate Research Assistant, Iowa State University-Currently at the University of Arkansas

Charles R. Hurburgh, Professor, Iowa State University

Outputs

Managing geographic variations in protein and oil is one way to maximize the value potential of soybeans for handlers and processors. An Iowa cooperative had been sourcing soybeans for processing from its own elevator locations, based only on proximity to the processing plant. The company wanted to know whether this strategy was maximizing the net processing value of the soybeans. During the Fall 2018 soybean harvest, soybean samples were collected from 32 country elevator locations of this company. Samples were analyzed using near-infrared spectroscopy (NIR), and protein and oil content data were entered into an Estimated Processing Value (EPV) model to determine value differences of soybeans among elevator locations. Variability among location averages represented a $0.23/bushel EPV spread. Soybean quality did not vary significantly over the harvest season, so accurate distribution decisions could be made at the beginning of the season.

The sample collection was repeated in the fall of 2019. Harvest 2019 was very late, but at the time of this writing (1/2020) the locational patterns and value estimates appear to be repeating those of the 2018 data.

Random and systematic errors from testing and measurement instruments also impact marketing decisions. To determine the incidence of random errors, an Excel-based simulation model was used with three test cases. The introduction of random error reduced the value differences between locations, which made the discrimination of high-value locations from average or low-value locations difficult. At double the random error of calibration for the NIR instruments involved, only one location was significantly more valuable than the rest. The validity of marketing decisions using composition data depended highly on the error in sample analysis. Standardized measurements will be essential for widespread acceptance of component pricing in soybeans.

Outcomes/Impacts

Selective collection of soybeans at a given processing plant, by oil and protein content, appears to add significant value to the processor, at reasonably low acquisition costs so long as geographical area and not individual trucks were used to identify high value soybeans. Analytical error will be a major risk that will need to be controlled so that potential value is not lost in analytical variability.

Funding Sources

United Soybean Board

Contacts

Charles R. Hurburgh, Iowa State University, tatry@iastate.edu, 515-294-8629

Title

Strategies for Selective Handling of Soybeans to Maximize Soybean Processing Value.

By

Hurburgh, C. R., Professor, Agricultural & Biosystems Engineering, Iowa State University
Barr, Bennett, Graduate Research Assistant

Outputs

An Iowa grain firm with soybean processing capacity assessed the protein and oil from the 2018 crop as received at locations providing soybeans to the processing plant. Three high-volume locations used NIR units to test each incoming load. Other locations (36) were asked to provide 2 composite samples per harvest day to one of the testing locations. The overall goals were to determine if there were large enough protein and oil variations to selectively segregate soybeans either load by load or by location to be shipped to the processing plant. A secondary goal was to update an existing Estimate Processing Value (EPV) model to determine value differences of soybeans from 32 elevator locations. The overall averages for all samples were 32.7% protein and 20.1% oil.

Outcomes/Impacts

The total of protein and oil (SUM) was highly correlated with processing value as estimated by our new SPROC processing model. One percentage point of SUM is worth about 15 cents per bushel to the expeller processing plant. Variability among elevator locations averaged $0.23 per bushel in the EPV spread. Analytical errors were simulated and included in the model, which decreased the apparent value spread between locations. Implications of the research demonstrate the importance of accounting for errors in analytical tasks. The company will expand the testing and develop an action plan for capitalizing on locational differences as a result of this research.

Significant improvements in processing margins appear possible by managing the logistics of soybean shipments from receiving locations to the processing plant versus other market locations.

Funding Sources

United Soybean Board, Elevator Collaborator, Iowa Grain Quality Initiative

Title

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

By

Dirk E. Maier, Agricultural & Biosystems Engineering, Iowa State University
Charles R. Hurburgh
Erin L. Bowers
Connie L. Hardy, Value Added Agriculture

Outputs

A continuing education course in Advanced Grain Elevator Management was offered three times in 2018 (to 90 professionals). The FSMA Preventive Controls Qualified Individual short course was offered twice in 2018 to qualified feed industry professionals. In both short courses, Iowa State University partnered with industry sponsors and other professional stakeholders, such as the Iowa Agribusiness Association to recruit attendees and offer the course.

Three workshops were offered to 68 processing industry professionals on near infrared analysis. A support service for firms who wish to improve their food and feed safety programs was initiated. This program conducted 11 projects in FY 2019 with several industrial clients and created an estimated impact of $8M and creation or retention of 60 jobs.

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.

Funding Sources

Extension Funding.

Various other sources.

Title

Understanding and Capturing Economic Value within Changing Grain Marketing Landscapes.

By

Anton Bekkerman, Montana State University
David Weaver

Outputs

Numerous research projects have been developed and either published, under review, or in progress that directly relate to Objectives 2 and 3. The work "Agro-economic returns were reduced for four years after conversion from perennial forage" looks at optimal conversion of land that has been enrolled in the Conservation Reserve Program. Specifically, we consider returning land into production using a cropping system that includes peas.

Multi-institutional work between Montana State University and Washington State University resulted in the publication, "Impacts of Agricultural Management Systems on Biodiversity and Ecosystem Services in Highly Simplified Dryland Landscapes." In this work, we consider how dryland crop and animal production regions with high economic and social values can be optimally managed to maintain economic, environmental, and social sustainability. While previous studies assessing the impacts of agricultural management systems on biodiversity and their services focused on more diversified mesic landscapes, there is a dearth of such research in highly simplified dryland agroecosystems. An analysis of the land use changes due to agricultural expansion within the Golden Triangle, a representative agricultural area in the NGP, indicated that the proportion of land conversion to agriculture area was 84%, 8%, and 7% from grassland, riparian, and shrubland habitats, respectively.

A key empirical study assessing the role of adjuvants and formulation in the mitigation of risk due to loss of insecticidal products in spray applications show that spray drift can be reduced by more than 60% by the type of formulation and also decreased by more than 35% in combination with certain specific products added to insecticidal spray. This is due to the influence of the formulation or adjuvant on the size of the droplets in the agricultural spray. These findings have particular importance when considering the balance between maximizing the efficacy of insecticidal applications while minimizing nontarget risk.

Numerous blog posts and recorded podcasts directly address applied, measurable issues related to wheat markets in a timely and relevant fashion. This year, topics focused on international trade issues, wheat quality valuation and volatility, and issues in the pulse markets. For example, the posts "New Tool for Assessing Historical Montana Wheat Basis" provided information and web-based tools that helped grain producers better understand the market opportunities of marketing their grain across different grain quality levels. The post " The 2019 wheat market looks a lot like it did in 2016" discussed the state of wheat markets in the northern Great Plains and provided information about how wheat quality valuation could be affected in the upcoming marketing year.

The project also collected farmer-level survey information regarding variety selection. The farmer-level survey collected information about farmers' choices regarding the wheat and barley varieties that they chose to plant. The survey also evaluated factors that impact producers' decisions to choose different varieties, including quality attributes of the crop. As new varieties are introduced into the market each year, the survey provides important information on the state of the grain industry in Montana.

Lastly, Bekkerman contributed to the NC-213 mission by serving as the group's chair and helped organize the 2019 NC-213 annual meeting in Ames, IA. He has continued to serve in the outgoing chair role after the annual meeting, participating in the group's quarterly phone conferences and leading the group's award process.

Outcomes/Impacts

The work on the land transition after participating in the Conservation Reserve Program resulted in a number of empirical insights. After adjusting grain prices using historical discounts and premiums for test weight and protein content at Montana grain elevators, we found that pea-wheat net returns were reduced for four consecutive years in three economic scenarios, and for 2 yr in a fourth scenario by a 4-yr cumulative average of (USD) $731 ha-1 (45%). Accounting for wheat quality differences and uncertainty in market valuation of those differences was particularly important and led to significantly different management outcomes. We conclude annual crop yield and economic returns were compromised for 4 yr following 10 yr of an alfalfa-dominated perennial cropping system.

The multi-institutional collaborative research about agricultural management also yielded several interesting outcomes. Our results showed the system simplification was associated with a potential reduction of pollination services. Also, our economic analysis projected that if 30% parasitism could be achieved through better management systems, the estimated potential economic returns to pest regulation services through parasitoids in Montana alone could reach about $11.23 million. Previous work by Bekkerman and Weaver considered optimal management strategies to minimize economic losses in high-quality wheat production resulting from the wheat stem sawfly. Although land use changes due to agricultural expansion and industrialized farming threaten the sustainability of dryland agroecosystems, this impact can be partially offset by coupling ecologically-based farming practices with adaptive management strategies.

Farmer-level survey results offer important information for understanding the likely grain quality that will be supplied by Montana producers during the 2019/20 marketing year (and likely for the next 2-3 marketing years). This information is particularly useful to domestic and foreign buyers of Montana grain, who make purchasing decisions based on their knowledge about the grain quality characteristics that are likely to be procured from Montana elevators.

During the reporting period, the www.AgEconMT.com project and website, on which blog posts and podcasts are posted, received over 15,000 visitors. Many of these visitors are consumed information related to wheat quality and marketing issues. The project has also had a significant impact in social media, with over 150,000 individuals having seen blog posts and podcasts distributed via the Twitter platform.

Publications

Adhikari, S., A. Adhikari, D. Weaver, A. Bekkerman, F. Menalled. 2019. “Impacts of Agricultural Management Systems on Biodiversity and Ecosystem Services in Highly Simplified Dryland Landscapes.” Sustainability. 11(11):3223-3239.

Miller, P., A. Bekkerman, J. Holmes, C. Jones, R. Engel. 2019. “Agro-economic returns were reduced for four years after conversion from perennial forage.” Agronomy Journal. 111(5):2292-2302.

Preftakes, C., J. Schleier, G. Kruger, D. Weaver, R. Peterson. 2019. “Effect of insecticide formulation and adjuvant combination on agricultural spray drift.” PeerJ. 7(e7136):1-20.

Title

Mitigating the Separation of Dust from Grain Kernels.

By

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Outputs

Grain dust explosions occur when dust accumulates beyond the minimum explosible concentration in a confined space and is exposed to oxygen and an ignition source. High dust concentrations that occur with grain handling operations can cause other serious problems, including health and safety risks from dust inhalation. Facilities that handle grain can be at risk of explosion if dust particles are released during handling producing spaces with sufficient dust concentration for explosion. Workers in the facilities may be at risk from inhaling the dust.

The adhesion force that holds the grain dust particles to the grain itself is an important factor in better understanding grain dust and mitigating the separation of dust from grain kernels. To evaluate adhesion forces, a centrifuge was used to separate the dust from the grain kernels and determine the forces required for separation. There was large variability in dust concentration between the five samples tested. After repeatedly centrifuging the samples, we found there was a subset of the total adhered dust removed at the lowest centrifuge speed (1000 rpm), followed by a second subset with much higher attachment strength that was only removed with centrifugation at 3000 to 4000 rpm. This indicates that a portion of the total grain dust is likely to be detached during any physical handling of corn, but that care should be taken that the impact velocities of grain kernels not grow high enough to release the additional quantities of dust that are more strongly attached.

We also evaluated how dust particles attach to the grain surface and later become dislodged creating dangerous dust clouds. The dust particle shape and structure are factors thought to influence the strength of attachment of the dust to the grain. To better understand these factors, dust samples were analyzed for physical characteristics such as circularity, length to width ratio, surface roughness, attachment strength to corn, and particle size. The freshly harvested corn samples contained more small particles with low circularity than older lower quality samples. The large particles were determined to be starch, while the smaller particles were more likely soil. Dust particles that were more strongly attached to corn kernels had lower surface roughness measurements than those that were weakly attached, although the difference was negligible in some corn samples.

Outcomes/Impacts

These results improve our understanding of how dust particles are removed from corn to cause dust cloud generation and about the relationship of dust particle shape and structure to the release of grain dust to the atmosphere. This information will be valuable for grain handlers and grain elevator operators for evaluating and improving their handling procedures to reduce their safety and health hazards and air pollution problems.

Publications

Plumier, B.M., Zhao, Y., Casada, M.E, Maghirang, R.G., Ambrose, R.P.K. 2020. Dust content and adhesion characteristics of five corn samples. In Press: Transaction of the ASABE.

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