NC-213

(The U.S. Quality Grains Research Consortium)

2020 ANNUAL PROGRESS REPORTS

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MARKETING AND DELIVERY OF QUALITY GRAINS AND BIOPROCESS COPRODUCTS

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The Industry Advisory Committee

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:

AgriGold Hybrids ..... Chuck Hill (Chair 2012 – Present) – 2010-Present

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Consolidated Grain and Barge ..... James Stitzlein, Chair – 1997-2012

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

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

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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.

[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

Physical Disturbance as a Non-chemical Approach to Control Weevils in Stored Maize.

By

Brumm, T J., Associate Professor Agricultural and Biosystems Engineering, Iowa State University
Sserunjogi, M., Graduate Research Assistant, Agricultural and Biosystems Engineering
Bern, C.J., Professor Emeritus, Agricultural and Biosystems Engineering
Maier, D.E., Professor, Agricultural and Biosystems Engineering

Phillips, T.W., Professor, Entomology, Kansas State University

Research Updates/Outputs

Physical disturbance of infested maize has been effective in reducing populations of weevils in stored maize. Unlike chemical treatment, disturbance is simple, cost effective and does not leave residues in the food supply chain. Therefore, our study investigated physical disturbance as a non-chemical approach to suppress maize weevils in stored maize. Storage containers disturbed once per day (24 h) were more effective than 8 h, 12 h and undisturbed containers in suppressing maize weevil populations during grain storage. Disturbance as a postharvest strategy to control weevils holds great potential for the smallholder farmers to protect their stored maize. The preliminary study also documented that physical disturbance can be scaled-up using commercially available stirring machines to suppress insects in grain bins with a storage capacity up to 1651 Mg.

Study 1: Design and construction of an automated physical disturbance machine to control stored grain insect pests.

The first experiment designed, constructed and tested the automated disturbance machines with jars of infested maize rotated through about 1.25 revolutions in 3 seconds. The initial population of 25 live maize weevils reduced in a range of 1 to 4 weevils at all machine run times. The absence of physical damage on the appendages of adult maize weevils indicated that the selected disturbance rate of 1.3 m/s would not directly injure adult maize weevils during the disturbance experiment.

Study 2: Physical disturbance time interval for control of maize weevils in stored maize.

The second experiment used the disturbance machines to determine the effective disturbance over time to reduce populations of maize weevils. The results showed that disturbance intervals of 8, 12 and 24 h reduced the populations of maize weevils by 75%, 95% and 94%, respectively, compared to the undisturbed jars after 160 days of maize storage. In addition, the results indicated that disturbance once per day was the best interval in controlling weevil populations after 160 days of maize storage. The quality of maize in the disturbed jars was better than that in the undisturbed jars when tested for moisture content, test weight, broken corn and foreign material (BCFM), insect damage and mold damage.

Study 3: Mechanical stirring of maize stored in on-farm steel bins to control maize weevils.

The third experiment was a preliminary study that evaluated the effect of mechanical stirring of infested maize on the population of weevils in a corrugated steel bin filled with 127 Mg of maize. While the population of live maize weevils in the unstirred bin was increasing, stirring achieved 100% control after 40 days. Additionally, maize in the stirred bin was of a better quality compared to maize in the unstirred bin when tested for moisture content, test

weight, insect damage and mold damage. Mechanical augers concentrated broken kernels and fine portion of the foreign material to the bottom of the bin.

Funding Sources

Funding for this study was provided by Sukup Manufacturing Company, Sheffield, Iowa, the Iowa Agriculture and Home Economics Experiment Station, and Dr. Floyd Herum, Ft. Dodge, Iowa who provided funds for the automated disturbance machines.

Publications

Thesis

Sserunjogi, M. (2020). Physical disturbance as a non-chemical approach to control weevils in stored maize. Unpublished M.S. Thesis. Iowa State University, Ames, USA.

Oral Presentations

Sserunjogi, M., Bern, C. J., Brumm, T. J., Maier, D. E. (2020). Physical Disturbance Time Interval for Control of Maize Weevils in Stored Maize. ASABE Virtual Annual International Meeting. Omaha, Nebraska, July 13-15, 2020.

Sserunjogi, M., Bern, C. J., Brumm, T. J., Maier, D. E., Phillips, T.W. (2020). Mechanical Stirring of Maize Stored in on-Farm Steel Bins to Control Maize Weevils – a preliminary study. ASABE Virtual Annual International Meeting. Omaha, Nebraska, July 13-15, 2020.

Poster Presentations

Sserunjogi, M., Brumm, T. J., Bern, C. J., Maier, D. E. (2019). Physical Disturbance Time Interval for Control of Maize Weevils in Stored Maize. Norman Borlaug Graduate Student Poster Competition. Ames, Iowa, October 14, 2019.

Title

NIR Hyperspectral Imaging for Animal Feed Ingredient Applications.

By

Dantes, P.T.G., Former Graduate Research Assistant, Iowa State University, Hurburgh Research Group and I.G.Q.I. Extension Group
Hurburgh, C. R., Professor

Outputs

Near-infrared hyperspectral imaging (NIR HSI) was explored for animal feed applications. Its ability to provide chemical composition of the sample at the pixel level provides an advantage over the typical NIR spectroscopy, especially in potential on-line applications. A literature review was presented that highlights the applications of NIR HSI on grains, oilseeds, and animal feed ingredients.

In our first study, a Corning NIR HSI instrument was used to predict protein and oil content in soybean meal and visualize predicted protein distribution over the entire soybean meal sample. Preprocessing by standard normal variate and Savitzky-Golay derivative was effective in improving calibration model performance. The NIR HSI instrument was also compared with two commercially available single-point NIR spectrometers which are typically used in the grain and feed industry. Absorbance spectra from the NIR HSI instrument were relatively close to those from the two NIR instruments in most of the wavelengths. Regression coefficients from soybean meal protein model calibration highlighted the similarities in the contributing variables of the three instruments.

In the second study, lysine concentration was determined in soybean meal and dried distillers' grains with solubles (DDGS) using NIR HSI in combination with partial least squares regression or spectral angle mapper (SAM) classification. Score plots from principal component analysis separated pure lysine spectra from soybean meal and DDGS. Increasing the SAM maximum angle also increased the model calibration performance. Overall, both PLS regression and SAM classification obtained promising results thereby indicating the potential of this technology to be used in evaluating amino acid concentration in animal feeds.

Outcomes/Impacts

Rapid measurement (at-line) of micro-nutrients, especially amino acids, has always been a desired technology for feed manufacturers. For amino acids, even presently available near infrared laboratory solutions effectively rely on correlations of amino acids with protein in individual ingredients to make these estimates. Factors of safety versus animal nutritional needs are normally used in formulation, which leads to additional costs per ton of $5 or more, in more expensive synthetic ingredients or overfeeding of higher quality base ingredients. This is $1,500,000 per year for a common 300,000 ton per year high production mill.

No ingredient is uniform; ingredient components are treated as averages over some testing or purchasing interval, in the same way that feed safety is monitored over some control interval. On line measurements with at-line precision open the opportunity for rapid process control, with further savings or efficiencies beyond those generated from more accurate averages. The competitive mixing economics and animal performance risk management could accrue rapidly and could be capturable at the local milling/feeding level.

Publications

Dantes, Princess Tiffany Galaura, "NIR hyperspectral imaging for animal feed ingredient applications" (2020). Graduate Theses and Dissertations. 18113. https://lib.dr.iastate.edu/etd/18113

Funding Sources

Instrument manufacturers.

IGQI.

Contacts

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

Title

Optimization of Ethanol Production Processes with Protein-rich Coproducts.

By

Rosentrater, K.A., Associate Professor, Agricultural and Biosystems Engineering, Iowa State University
Oliveira, M.C., Former Doctoral Student, Agricultural and Biosystems Engineering
Xie, K., Former Master's Student, Agricultural and Biosystems Engineering

Research Updates/Outputs

This project aimed to improve the understanding of ethanol production processes with protein-rich coproducts. To this end, mechanical and chemical fractionation systems were examined for cost impacts and optimal production scales were determined. Using engineering data gathered on properties of Distilled Dried Grains with Solubles (DDGS), an ASABE Standard was assembled and published. The information from this project will assist ethanol plants as they consider implementing new technologies using high-protein feed ingredients.

Funding Sources

Funding for this study was provided, in part, by the Distillers Grains Technology Council.

Publications

Rosentrater, K.A. 2020. ANSI/ASABE D606 Properties and Relationships for Distillers Dried Grains with Solubles (DDGS). St Joseph, MI: American Society of Agricultural and Biological Engineers.

Oliveira, M.C. and K.A. Rosentrater. 2020. An environmental and economic analysis of flocculation technology applied to a corn-based ethanol plant. Processes, 8(271), 1-20.

Xie, K. and K.A. Rosentrater. 2019. Optimization of fractionation of distillers dried grains with solules (DDGS) through a gravity separator. Recent Advances in Food Science, 2(4), 217-239.

Title

Marketing and Delivery of Quality Grains and BioProcess Coproducts.

By

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

Outputs

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 objective 1. The long-term goal of this project is to provide safe and healthy wheat to maintain a vibrant wheat market and establish wheat from the Great Plains as high quality. 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. One product that has been the vehicle for several outbreaks is raw cookie dough. Therefore, we examined high pressure processing (HPP) as a means of reducing pathogens in cookie dough made from wheat flour. Endogenous microbial populations were marginally reduced (0.2-0.5 log CFU/g) by HPP treatments. However, treating the dough at 600 MPa for 6 min significantly reduced counts of inoculated Escherichia coli by as much as 2.0 log CFU/g. Dough and cookie physical characteristics did not differ significantly among HPP-treated and control doughs.

As wheat is milled into flour, there is a substantial risk of cross-contamination by microorganisms potentially inhabiting the milling equipment. We assessed the levels of microbial contamination associated with milling equipment and wheat grain as it progressed through a milling facility. Equipment used to clean, and temper wheat grain was found to harbor substantial populations of aerobic mesophilic bacteria, Enterobacteriaceae, and molds. Generic E. coli was found in 2 instances on cleaning equipment at an average of 0.4 log CFU/10 cm2. Coliform counts increased markedly in wheat kernels and milled fractions after passing through the different milling steps. This study identified critical control areas and equipment where
cross-contamination is likely to occur during milling. Appropriate sanitary measures should, therefore, be implemented in the mill to minimize the risk of microbial contamination during wheat milling.

We also received funding to examine protein digestibility in wheat. Therefore, the in vitro protein digestibility of breads made with 21 cultivars of wheat introduced or released in the USA between 1870 and 2013 were evaluated. Three older cultivars displayed lower digestibility than the other cultivars: 42.0 ± 0.3 mol% (primary amino N/total N) versus 34.7 ± 0.7 mol%; $P < 0.001$. We examined differences in glutenin and gliadins using SE-HPLC, but these changes were not related to protein digestibility. Thus, other differences in protein composition or other flour components may contribute to diminished digestibility of the three older cultivars. This study identified differences in protein digestibility among wheat cultivars that may have important implications for human nutrition. Further investigation is required to determine the specific characteristics that differentiate high- and low-digestibility wheat cultivars.

Outcomes/Impacts

We have established non-thermal (high-pressure) processing conditions to reduce microbial contamination in raw cookie dough. The results of this study suggest that high-pressure processing has the potential to improve the microbiological quality of wheat-based cookie doughs. However, variations in food matrix composition must be considered because some food constituents, such as sugar and fat, may protect microorganisms against pressure-induced inactivation.

Our survey of wheat milling equipment has provided critical control areas and equipment where cross-contamination is likely to occur during milling. In particular, equipment used to clean and temper wheat grain was found to harbor substantial populations of microorganisms. Therefore, appropriate sanitary measures should, be implemented at these sites to minimize the risk of microbial contamination during wheat milling.

Publications

Sabillón L, Stratton J, Rose DJ, Bianchini A. Microbiological survey of equipment and wheat-milled fractions of a milling operation. Cereal Chemistry.

Sabillón L, Stratton J, Rose DJ, Eskridge K, Bianchini A. Effect of high-pressure processing on the microbial load and functionality of sugar-cookie dough. Cereal Chemistry.

Gulati P, Brahma S, Graybosch RA, Chen Y, Rose DJ. 2020. In vitro digestibility of proteins from historical and modern wheat cultivars. Journal of the Science of Food and Agriculture 100: 2579-2584.

Funding Source(s) and Amount(s)

Rose D, Baenziger PS, Simsek S, Green A. Characterizing protein digestibility and celiac antigenicity of historical and modern wheats. The Andersons Research Grant Program Team Competition.

Title

Effect of Moisture Before Harvest on Grain Quality.

By

Manthey, F.A., North Dakota State University, Fargo
Cabas-Lühmann, P.A.

Outcomes/Impacts

Impact. Wheat products have a narrow profit margin. Durum wheat industry monitors weather during grain fill and harvest. By understanding the impact of initial kernel moisture content, the length of time exposed to moisture, temperature, and the number of wet/dry cycles on grain quality allows durum wheat industry to anticipate grain quality in a particular region prior to harvest.

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Major activities completed / experiments conducted: Experiments were conducted to determine the effect of initial grain moisture content (13, 14, 15, 16, and 17%), temperature (5 and 24°C), and wet/dry cycles involving bulk distilled water and with high relative humidity (80 to 85%) on the hydration of durum wheat grain and their effect on physical grain quality. Grain samples consisted of three bulk samples which were used as replications. Soaking times ranged from 15 sec to 12 h. Grain quality tests included kernel moisture content, test weight, 1000-kernel weight, vitreous kernel content, kernel color, and kernel size distribution.

Summary statistics and discussion of results: Grain was affected more by damp conditions when it had low than high moisture content. Thus, rainfall or heavy dew occurring when kernel moisture was high had little or no effect on grain quality but had significant affect when grain moisture content was low. When the grain moisture was low, a single exposure to moisture, bulk moisture or high relative humidity, was enough to reduce grain quality. Most of the reduction in grain quality seemed to be related to the swelling effect of moisture on the bran layer.

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

Publications

Cabas-Lühmann, P. A. and Manthey, F. A. 2020. Effect of hydration on physical grain quality of durum wheat. Cereal Chemistry, 97:877– 887. https://doi.org/10.1002/cche.10311. NIFA Support was acknowledged for this publication.

Title

Extraction and Characterization of Plant Proteins from Byproduct of Oilseeds including Distiller's Dried Grains with Solubles (DDGS) and Flaxseed Meal (FM).

By

Rao, J., North Dakota State University, Fargo

Outcomes/Impacts

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Major activities completed / experiments conducted: Experiments were conducted to compared the structural and functional properties, and aroma profiles of flaxseed proteins extracted from golden whole flaxseed (WF) and flaxseed meal (FM). In terms of extraction of zein from DDGS, the influence of particle size of DDGS (raw, milled sample), solvent type (e.g., ethanol, 2-propanol), concentration (60%, 70% and 80%) and reducing agents on zein purity, recovery yield and functionality was investigated.

Data collected: The extraction yield, chemical compositions, molecular weight and structural properties of plant proteins were characterized. Functional properties of plant proteins including solubility, surface hydrophobicity and thermal properties.

Summary statistics and discussion of results: For the protein properties obtained from flaxseed, results showed that flaxseed proteins obtained from WF and FM reached different purities of isolate (FPI) and concentrate (FPC), respectively. Consequently, two kinds of proteins differed significantly in terms of molecular, structural properties and flavor profile. Both SDS–PAGE and size exclusion chromatography (SEC-HPLC) results suggested that FPC consisted of a larger proportion of low molecular weight fractions with greater heterogeneity than FPI. The isoelectric point (IEP) of the two proteins was significantly different, being pH 4.2 and 3.0 for FPI and FPC, respectively. This was because of the presence of mucilage in FPC. In general, FPI presented higher foaming capacity than FPC at both neutral (pH 7.0) and acidic pH (pH 3.5) while FPC exhibited higher thermal stability than FPI. In terms of flavor profile, FPC exclusively contained (Z)-3-hexen-1-ol, 1-octen-3-ol, and (E)-3-octen-2-one, which can be used to differentiate FPC from FPI.
For the protein (zein) properties obtained from DDGS, 70% ethanol with milled powder has the highest protein purity (92.4%), extraction yield (18.3%) and higher thermal stability among all tested parameters. All zein extracted from DDGS had similar secondary structure of protein profile compared to commercial zein product. However, zein produced from DDGS contains the mixture of γ-zein and α-zein, whereas the commercial zein is mainly compose of α-zein. As a results, the functionality of zein extracted from DDGS showed distinct profile than that of commercial zein.

Key outcomes or other accomplishments realized: Flaxseed protein isolate (FPI) can be obtained from whole flaxseed. By contrast, flaxseed protein concentrate (FPC) can be prepared from flaxseed meal. Removing mucilage from flaxseed prior to protein extraction could improve the protein extraction yield. In terms of extraction zein from DDGS, 70% ethanol with milled DDGS sample is recommended method for extraction of zein.

Future Plans

There were no issues or problems during the current reporting period. During the next reporting period we will continue to optimize the functionality of plant proteins from wide-spectrum of oilseeds and grains in order to address the goals and objectives of this project.

Publications

Full Citation:

Yang Lan, Jae-Bom Ohm, Bingcan Chen, Jiajia Rao (2020). Physicochemical properties and aroma profiles of flaxseed proteins extracted from whole flaxseed and flaxseed meal. Food hydrocolloids, 104, 105731. NIFA Support was not acknowledged for this Publication.

Other – Full Citation:

Yang Lan, Jiajia Rao. Poster: Effect of Demucilaging Method on the Structural, Rheological and Tribological Properties of Flaxseed Protein. In: 2020 American oil chemists' society (AOCS) annual meeting. June, 2020. NIFA Support was not acknowledged for this abstract.

Title

Improving Quality of Hard Red Spring and Durum Wheat.

By

Simsek, S., North Dakota State University-Fargo
Manthey, F.

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 phytopathogenic agents Fusarium graminearum and Fusarium culmorum are responsible for Fusarium head blight (FHB), in wheat, causing negative effects on crop yield and grain quality, as well as the accumulation of a highly water-soluble mycotoxin, known as Deoxynivalenol. Consumption of grain contaminated with DON carries negative effects for both animals and humans. Detrimental effects of Fusarium infection on wheat protein structure and rheological properties have been reported, including a decrease in total protein content, diminished dough consistency, and a reduction in bread loaf volumes. The market price for Fusarium infected wheat is severely reduced since FHB infection can be associated with low test weight grains, damaged kernels (scabby kernels) and, even in kernels that look normal, mycotoxin accumulation. The wet milling process can be a valuable alternative for deoxynivalenol (DON) contaminated wheat grain, taking advantage of DON water solubility. Wheat gluten is not only a valuable ingredient for the food industry but it is also considered an important item within a global trade context. Wheat flour can be fractionated into water-soluble material, fiber, starch, and gluten by wet milling processes. The present research was conducted on hard red spring wheat (HRSW) and durum wheat (DW) samples contaminated with DON.

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Major activities completed / experiments conducted
Durum wheat samples were obtained during the 2015–2016 harvest season; samples came directly from grower fields, farm bins, and local elevators. Two bulk samples of durum wheat were made. The first bulk sample was a blend of three durum wheat samples that contained DON levels of 12.5 mg/kg, 10.8 mg/kg and 13.4 mg/kg, respectively. The second bulk sample was a blend of two durum wheat samples that did not contained detectable DON levels. Similarly, two samples of Hard Red Spring Wheat (HRSW) were made. The first bulk sample contained HRSW cultivars ND826 and MS Chevelle that contained DON levels of 6.8 mg/kg, and 1.9 mg/kg. These cultivars were grown, in 2016, at the North Dakota State University Langdon Research Extension Center (Langdon, ND). The second sample contained grain from the cultivar WB Mayville grown in 2016, at North Dakota State University Williston Research Extension Center (Williston, ND) that had no detectable DON.

Grain moisture content, ash content, protein content, total starch, and falling number were determined using AACCI Approved Methods 44–15.02, 08–01.01, 46–30.01, 76–13.01, and 56–81.03 (AACC, 2010), respectively. The samples were dry milled using a Brabender Quadramat Jr. roller mill that was configured to produce farina (HRSW) and semolina (Durum).

Gluten isolation was done using three different laboratory scale wet milling methods. The wet milling methods utilized low shear, medium shear or high shear for separation of gluten from semolina and farina. DON levels were determined in farina/semolina and in the wet milling fractions. DON determination was done by gas chromatography with electron capture detection (GC-ECD).

Rheological analysis of the gluten fractions was done using a controlled stress rheometer. Cone and plate (40 mm, 2°) geometry were used. The temperature was held at 25 °C. Dough samples (developed by optimum farinograph absorption and optimum mixing time) or gluten samples (0.3 g rehydrated in 10 mL of deionized water) were formed and then loaded onto the lower plate of the rheometer, then the upper plate was brought to 2 mm gap. The excess sample was trimmed. Frequency sweep tests were performed at a strain value of 1% (linear viscoelastic region) and within the range of 0.1–30 Hz.

Proteins were extracted for size-exclusion HPLC (SE-HPLC) using SDS and sonication to obtain SDS-extractable and SDS-unextractable fractions. The extracted proteins were analyzed using SE-HPLC. The separation of the proteins in the SDS-extractable and SDS-unextractable fractions was performed individually using an Agilent 1100 series narrow bore size-exclusion column. Data was analyzed using MATLAB software.

The experimental design was a randomized complete block with two factor factorial arrangement and four replications. The first factor was the wet milling method (three methods: Martin, medium shear, high shear) and the second factor was mycotoxin contamination (two levels: with and without DON). Data were subjected to analysis of variance using the ‘MIXED’ procedure in the Statistical Analysis System 9.4 (SAS Institute, Cary, NC, USA). Treatment means were separated by Fisher's Protected Least Significant Different (LSD) at $p < 0.05$. Correlation analysis was conducted using the ‘CORR’ procedure in the Statistical Analysis System 9.4 (SAS Institute, Cary, NC, USA).

Data collected: The first HRSW (HRSW 1) and DW (DW 1) sample SET contained high levels of DON, 6.0 mg/kg and 11.9 mg/kg, respectively. On the other hand, HRSW 2 and DW 2 were the controls and had no detectable DON levels. DON was found in all three dry milled fractions (farina/semolina, shorts, and bran) of HRSW 1 and DW 1 samples.

Overall, gluten purity, extraction, and recovery were not greatly affected by wheat species but were affected by the wet milling process and by the presence of DON in the sample. Regardless of the wheat type, the purity of the extracted gluten was greatest with the Martin process and tended to be similarly lower for the medium and high shear processes. The purity of gluten extracted using medium and high shear processes for HRSW and DW was higher in DON containing samples when compared to the control samples. None of the gluten fractions contained DON levels above the limit of quantification. DON removed from the gluten fractions was found in high levels in the residual water (water-soluble fraction).

The results of the SE-HPLC analysis indicates that higher protein in HRSW 2 and DW 2 farina and semolina samples, respectively, resulted in higher unextractable F1 levels. Regardless of the wheat type, for both, the second extractable fraction EP2, showed the highest percentage of protein, which was mainly composed of gliadin proteins. For the glutenin polymeric proteins (F1), farina and semolina samples that were not contaminated with DON had a higher absorbance area percent for unextractable fraction (UP1), when compared to those of DON contaminated samples. In contrast, extractable F1 percent (EP1) values were higher for DON contaminated samples than those of non-contaminated samples for HRSW and DW. The protein composition of the extracted gluten was also analyzed

by size exclusion HPLC. In addition to the three fractions analyzed for flour samples, another fraction (F4, 7.8–8.5 min) that was most likely hydrolyzed proteins in the wet milling process was included in the analysis of gluten SE-HPLC data. The F2 showed the highest absorbance for both extractable and unextractable fractions, regardless of the wheat type and DON levels. As expected, for both extractable and unextractable proteins the third (F3) and fourth (F4) fractions were lower when compared to the gluten forming protein fractions (F1 and F2).

Regarding the fundamental rheology properties of farina (HRSW 1–2) and semolina (DW 1–2) furthered wet milled in the present study, small deformation oscillatory measurements were run to evaluate if the presence of DON had an impact on the structure of dough formation. For both HRSW and DW, the viscoelastic soft solid consistency of dough was evident due to the prevalent higher G' over G" over all the tested frequencies (0.1–30 Hz). Interestingly, regardless of the presence of DON, the HRSW doughs behaved similarly, indicating that they had similar gluten strength. On the other hand, for DW doughs, the sample without detectable DON (DW 2) had higher moduli when compared to the sample exhibiting DON levels (DW 1), which means that DW 2 had a stronger gluten network than did DW 1. The extracted gluten samples from the different wet milling methods for both HRSW and DW samples was compared with a commercial vital wheat gluten sample. To illustrate how the differences in protein composition between the extracted gluten samples and the commercial gluten sample impacted functionality, dynamic oscillatory measurements were run. Overall, the typical viscoelastic behavior with moduli showing a frequency dependence was seen. However, differences were seen between the different wet milling methods. For instance, HRSW and DW gluten samples subjected to the Martin wet milling method had moduli values higher than those of the commercial wheat gluten.

Summary statistics and discussion of results: All fractions, except for farina (3 mg/kg DON), contained DON levels above 5 mg/kg, which exceeds the FDA advisory levels for consumption by humans and non-ruminant animals. The DON concentration followed the common trend of bran > shorts ≥ farina/semolina DON contamination.

Medium and high shear processing of samples without DON resulted in low purity gluten (40.7–48.3%), which is below the level that is commercially acceptable. Gluten extracted with the Martin process seemed to have similar purity whether the gluten was from HRSW or DW samples, and the gluten purity was not affected by whether the grain samples were contaminated with DON or not. The extracted gluten exceeded the minimum standard for commercial gluten (>75%). In this sense, the presence of DON seemed to affect the quality of gluten obtained from wet milling using medium shear or high shear processes, but not the gluten obtained from the Martin process.

From the observed results, it is evident that the high DON levels found in the residual water fraction were aided by the mycotoxin high solubility, which is in agreement with mycotoxin contaminated corn wet milling research when the wet milling process was applied to different dry milled wheat fractions that contained DON.

Quantitative changes of total protein along with compositional changes in protein exist between DON contaminated and non-contaminated samples. In other words, for the sample contaminated with DON, the extractable glutenin polymer fraction was higher and the unextractable glutenin polymer fraction was lower. When comparing gluten samples obtained from wet milling process, the gluten obtained from the medium shear process showed higher UV absorbance values for both extractable and unextractable F1 with the exception of HRSW gluten from the high shear process, which appeared to be higher in unextractable F1 than others.

Differences in rheological properties of the doughs can be explained by the size-exclusion HPLC chromatograms, which showed that DW 1 had higher buffer extractable polymeric proteins (EP1) and lower sonication extractable or buffer unextractable polymeric proteins UP1. Higher EP1 and lower UP1have been previously associated with a negative and a positive influence, respectively, on dough strength for durum samples, thus influencing semolina three-dimensional gluten network. These differences in the rheological characteristics of the extracted gluten are explained by the protein composition here EP1 and UP1 were notably higher and EP2 and UP2 were significantly

lower for the commercial gluten, than for the gluten samples obtained from Martin method. The F2 is primarily composed of gliadins and F1 is mainly composed of glutenin macropolymers.

Key outcomes or other accomplishments realized: This work has demonstrated the effectiveness of three laboratory-scale wet milling processes (Martin, medium shear and high shear processes) to remove DON from contaminated HRSW and DW samples. The wet milling processes yielded gluten, starch and water soluble fractions, but this research was focused on the study of the gluten fraction. After the wet milling processes, the extracted gluten had DON levels below the limit of quantification (<0.2 mg/kg). Regardless of the DON contamination, the size-exclusion HPLC analysis revealed that gluten samples obtained from medium shear and high shear processes were composed of more unextractable glutenins (UP1) than unextractable gliadins (UP2) compared to the gluten sample extracted from the Martin process. The proteins composition was used to assess their impact on fundamental rheology. In this sense, the lower proportion of gliadins versus glutenins yielded better rheological performance similar to the control (commercial wheat gluten). Therefore, the wet milling technique can be considered as an alternative option to process DON contaminated wheat to extract gluten that exhibits a potential application as food ingredient.

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:

López, A. M. M., Ohm, J. B., Manthey, F. A., Rao, J., & Simsek, S. Gluten extraction from deoxynivalenol contaminated wheat by wet milling. Food Control, 120, 107513. NIFA Support was not acknowledged for this Publication.

Title

Monitoring Stored Grain to Manage Quality.

By

Olenloa, Akhere, Agricultural & Biological Engineering, Purdue University, West Lafayette, Indiana, Visiting Graduate Research Scholar
Ileleji, Klein, E., 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.

We monitored the temperature, RH and CO2 levels of corn stored in three mini-silos made up of 55-gallon steel drums. Mini-silos contained corn at 14.6% moisture, corn at about 18% moisture in a canister with corn at 14.6% and insect pests in a canister with corn at 14.6%. The trend showed that a drop or rise in CO2 levels at the plenum similarly results to affects the CO2 level at the headspace (Figure 1). This indicates the presence, movement and diffusion of CO2 across the entire grain mass. The temperatures at the grain top, middle and bottom were close with similar variation. They also followed the trend of the ambient temperature. This is an indication that ambient temperature also influences temperature variations in the storage bins. Generally, it was observed that a decrease in the temperature levels also results to a decrease in the CO2 levels. This is an indication that temperature influences the expansion of the CO2 gases in the grain mass.

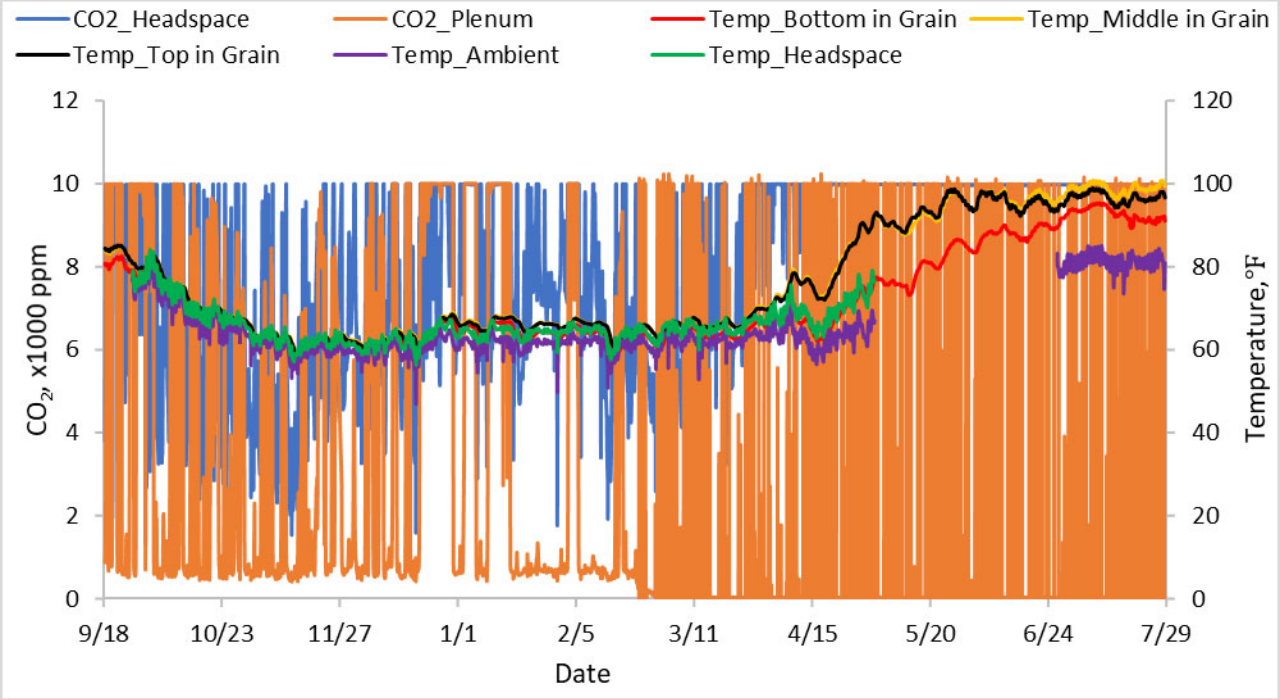

Figure 1: Grain at Normal Moisture Content (14.6%)

Outcomes/Impacts

The challenge in correctly interpreting data of temperature, moisture and CO2 profiles of the stored grain bulk is still an issue. This research effort in collaboration with the industry will provide operations personnel 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

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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 – Soil and Crop Sciences Dept. and Office of the Texas State Chemist
Lee, K.M.
Li, W.

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

Outputs

Standard Raman and surface-enhanced Raman spectroscopic techniques coupled to chemometric algorithms were applied to develop the spectroscopic method for early identification and rapid quantification of water-soluble vitamins (WSVs) including thiamine, pantothenic acid, niacinamide, pyridoxine, biotin, and riboflavin. WSVs are being used as dietary supplements in a variety of grain-based food and feed products and critical in human and animal health because of the non-synthesis of the vitamins in human and animal bodies. In this study, animal feed samples were spiked at different ranges of concentrations of WSVs and measured by standard and surface-enhanced Raman spectroscopy. The collected raw spectra were preprocessed to remove spectral artifacts prior to the development of chemometric models. The processes spectra of different concentration groups displayed the intensity of characteristic Raman peaks proportional to a concentration of WSVs. The calibration models for qualitative and quantitative analysis also showed high accuracy and precision for training and validation datasets and no statistically significant difference between model-predicted and actual concentrations of the spiked samples. The findings and observations from this proof-of-concept study imply that the proposed spectroscopic methods would be a powerful and convenient tool for the analysis of WSVs in grain-based feed products.

Fumonisins are toxic by-products of mold growth produced by Fusarium verticillioides, F. proliferatum and other Fusarium species and are commonly found on corn. The state of Texas provides the ideal environment for fumonisin accumulation with humidity followed by dry weather. A study funded by the NC-213 Anderson Grant Endowment administered by the Ohio State University involved managing fumonisin risk the in the corn value chain by performing a comparison of a Meta-Analysis and Benchmark Does approach to address food safety, quality, and marketing systems of cattle. A PECO statement was developed that considered Purpose, Exposure, Comparator, and Outcome as the evaluation criteria for a preliminary literature search to identify articles of cattle exposed to dietary fumonisin. Additionally, a risk of bias criteria was established as a central decision and prioritization tool. New literature was uncovered that meet these criteria since FDA established its preliminary guidance for fumonisin in 2001. In 2011, the Office of the Texas State Chemist (OTSC) collaborated with the Risk Management Agency (RMA) of the United States Department of Agriculture (USDA) and the Texas grain industry to implement the OTSC's first co-regulation governance option, known as the One Sample Strategy (OSS), to aid in the effort of managing aflatoxin risk and the program was expanded to include fumonisin and deoxynivalenol in 2017. Shared governance, also known as co-regulation, in the form of risk management relies upon a government-private partnership in regulation using government-backed codes of practice or action plan, with the end result being a more connected and transparent marketplace. To determine if there was an economic benefit of shared governance to manage fumonisin risk a census of interviews was conducted among applicable One Sample Strategy participants to complete a macro level analysis, which focused on the Texas High Plains during 2017 due to the prevalence of the fumonisin levels that occurred in this region at this time. The results were evaluated by using the data gathered from

the interviews to determine the measure of value that specific costs and benefits provided. The findings of the specific cost and benefit value measures for each analysis was modeled in the form of an income statement. From the income statement, the Texas High Plains in 2017 netted a total economic value of $54.1MM. This concluded that there is an economic benefit of shared governance to manage fumonisin risk.

Changes in aflatoxin contamination was evaluated throughout the processing of cottonseed to cottonseed meal. We found a 4-fold to 5-fold increase in levels of toxigenic aspergillus species from the beginning to the end of the cottonseed meal process (acid and mechanically delinted). The higher loads were attributed to lower protein levels and higher fat acidity in the meal. These results were used as input for developing atmospheric cold plasma (ACP) treatment parameters for microbial reduction in cottonseed meal. ACP is a novel non-thermal treatment technology that has been shown to successfully inactivate bacteria, molds, yeasts and other pathogens on agricultural products including fruits & vegetables, herbs & spices, food grains & nuts and meat & meat products. ACP is generated by the input of electrical energy which is formed within a dielectric barrier discharge (DBD) device. The plasma is an ionized gas which consists of ions, electrons, neutral species, ultraviolet (UV) and visible light. There are many ground neutral species, as well as negative and positive species, produced in ACP ionization. We saw a 2.8 log reduction of toxigenic aspergillus for samples treated at 70kV for 3 minutes.

Distillers dried grain and solubles (DDGs) are a biofuel coproduct used in animal feed. The Office of the Texas State Chemist has collected and analyzed 381 samples for sulfur between 2011 and 2020. An initial evaluation of these data considered the sulfur content in cattle feed by growth stage and feeding regime. Rations were balanced by protein content and sulfur levels were categorized at 0.5%, 0.6%, 0.7%, 0.8% and 1.1% sulfur in feed originating from the used of DDGs. These data were further analyzed using stochastic modeling to assess the risk of polioencephalomalacia in cattle. Sulfur is a hazard identified in cattle by the United States Food and Drug Administration as part of the Food Safety Modernization Act that should be addressed in cattle feed where the potential risk of high sulfur content is likely. This project will enable feeders, feed mills and regulators to evaluate the risk and how it should be addressed in food safety plans.

Outcomes/Impacts

The developed spectroscopic techniques would be a simple and efficient analytical tool alternative to conventional wet-chemical methods for screening and real-time monitoring of water-soluble vitamins (WSVs) in food and feed samples at critical locations in the product distribution systems. Spectroscopic techniques and calibration models developed from the study may be more practically applicable for WSV analysis in complex sample matrices to help improve the safety of food and food products for human and animal health.

Outcome of the fumonisin risk assessment, based on an initial assessment of new literature, reveals there are insufficient scientific evidence to support changing existing FDA guidance. Producers, grain handles and consumers benefit from a share governance approach to manage mycotoxin risk as demonstrated in Texas.
The sulfur risk assessment for DDGs fed to cattle will assist ethanol plants and feed manufacturers better manage risk.

The findings on aflatoxin contamination can be used to understand how sample aflatoxin levels increase throughout post-harvest processing of cottonseed. Likewise, we now have a set of treatment parameters that can be used to treat samples of contaminated cottonseed and cottonseed meal.

Opportunities for training and professional development provided by project.

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

How have the results been disseminated to communities of interest?

Dissemination of results to communities of interest occur through agency newsletters to 5000 firms, journal articles, course offerings, websites, and face-to-face communications and through a list serve reaching approximately 10,000 regulatory risk managers globally.

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

Complete and publish sulfur risk assessment. Incorporate these and other contaminant data with probability charts in hazard guides for animal feed. Perform meta-analysis and benchmark dose analysis of literature involving fumonisin fed to cattle and perform an economic prediction of future incidents of fumonisin contamination with and without changes in FDA guidance and in the absence of blending fumonisin contaminated corn under state regulatory authority. Continue to monitor chemical and biological contaminants in feed. Validate MALDI-TOF instrumentation for contaminants. Validate micro-fluidics point of care analysis for fumonisin and aflatoxin contamination and biomarkers involving human exposure in collaboration with Cornell University and Waters/Vicam. AgriLife will collaborate with Cornell to develop a low-cost smartphone-based point-of-need platform for analyzing aflatoxin and fumonisin in maize through validating this testing platform at the OTSC laboratory, the Texas grain industry and at two public health laboratories in Kenya. The proposed assay will help in preventing the food safety violations specifically in resource limited settings, due to its point-of-need attribute.

Publications

Lee, K. M., Yarbrough, D., Kozman, M., Herrman, T. J., Park, J. H., Wang, R., and Kurouski, D. 2020. A rapid and convenient screening method for detection of restricted monensin, decoquinate, and lasalocid in animal feed by applying SERS and chemometrics. Food and Chemical Toxicology. 144: 111633.

Lee, K. M., Yarbrough, D., Kozman, M., Herrman, T. J., Park, J. H., Wang, R., and Kurouski, D. 2020. Rapid detection and prediction of chlortetracycline and oxytetracycline in animal feed using surface-enhanced Raman spectroscopy (SERS). Food Control. 114:107243.

Lee, K. M., Yarbrough, D., Kozman, M., Herrman, T. J., Park, J. H., Wang, R., and Kurouski, D. 2020. Sensitive SERS characterization and analysis of chlorpyrifos and aldicarb residues in animal feed using gold nanoparticles. Journal of Regulatory Science. 8: 1-14.

Park, J. H., Thomasson, J. A., Lee, K. M., Suh, C. P. C., Perez, J. L., and Herrman, T. J. 2020. VOCs determination by adsorbent-Raman system in food and botanicals. Analytical Methods. 12:595–1605.

Herrman, D. A., Brantsen, J. F., Ravisankar, S., Lee, K. M., and Awika, J. 2020. Stability of 3-deoxyanthocyanin pigment structure relative to anthocyanins from grains under microwave assisted extraction. Food Chemistry. 333: 127494.

Funding Source(s)

The Andersons Research Grant Program.

National Science Foundation

Office of the Texas State Chemist, Texas A&M AgriLife Research

Title

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

By

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

Outputs

Sorghum grain composition was measured and related to end-use quality traits for several different projects with several collaborators. The effect of environmental factors on sorghum grain composition was investigated and genetic studies were completed to identify genes that impact sorghum grain quality.

Outcomes/Impacts

Sorghum is a drought and heat tolerant crop important to arid areas of the central U.S. and an important crop for food and feed around the world. Sorghum's tolerance to abiotic stresses and resilience plays an important role in food security. While sorghum grain has important nutritional properties, there are grain quality attributes and nutritional factors that can be improved to enhance the value and utilization of sorghum. This research addressed those issues by identifying genes related to nutritional quality of sorghum; identifying new uses and markets for sorghum proteins; investigating how stored product insects feed and damage on sorghum grain; and providing methods to help facilitate the use of sorghum in fuel ethanol production.

Publications

Ioerger, B.P., Bean, S.R., Tilley, M., and Lin, H. 2020. Improved method for extracting sorghum polymeric proteins. J. Cereal Sci. 91, 102876.

Burgos, C.C., Cox, S., Ioerger, B., Perumal, R., Hu, Z., Herald, T.J., Bean, S.R., and Rhodes, D.H. 2020. Advancing provitamin A biofortification in sorghum: Genome-wide association studies of grain carotenoids in global germplasm. The Plant Genome. 13, e20013

Weerasooriya, D., Bandara, A., Dowell, F., Peiris, S., Bean, S.R, Perumal, R., Adee, E., and Tesso, T. 2020. Performance of grain sorghum hybrids resistant to acetolactate synthase (ALS) and acetyl coenzyme-A carboxylase (ACCase) inhibitor herbicides. Crop Science. In press

Xu, Y., Li, J., Xin, Z., Bean, S. R., Tilley, M., and Wang, D. 2020. Water-soluble sugars of pedigreed sorghum mutant stalks and their recovery after pretreatment. Applied Sciences. 10, 5472.

Peiris, K.H.S., Bean, S.R., and Tilley, M. 2020. Analysis of sorghum content in corn-sorghum bioethanol feedstock by near infrared spectroscopy. J. Near Infrared Spectroscopy. 28, 267-274.

Arthur, F.H., Bean, S.R., Smolensky, D., Cox, S., Lin, H., and Peiris, K.H. 2020. Development of Rhyzopertha dominica (Coleoptera: Bostrychidae) on sorghum: quality characteristics and varietal susceptibility. J. Stored Products Research. 87, 101569.

Duressa, D., Bean, S.R., St. Amand, P., and Tesso, T. 2020. Identification of α-kafirin alleles associated with protein digestibility in grain sorghum. Crop Science. 60, 2467-2478.

Peiris, K.H.S., Bean, S.R., and Jagadish, S.V.K. 2020. Extended multiplicative signal correction to improve prediction accuracy of protein content in weathered sorghum grain samples. Cereal Chem. 97, 1066-1074.

Pontieri, P., Triosi, J., Romano, R., Pizzolante, G., Bean, S.R., Tilley, M., Motto, M., Aletta, M., Del Guidice, F., Sicardi, M., Alfiano, P., and Del Guidice, L. 2020. Nutritional composition of selected white food-grade waxy sorghum variety grown in the Mediterranean area. Australian J. Crop Science. 14, 1525-1532.

Arthur, F.H., Bean, S.R., Smolensky, D., Gerken, A.R., Siliveru, K., Scully, E.D., and Baker, N. 2020. Development of Tribolium castaneum (Coleoptera: Tenebrionidae) on sorghum milling fractions. J. Stored Products Research. 87, 101606.

Ostmeyer, T., Bheemanahalli, R., Srikanthan, D., Bean, S.R., Peiris, K.S.H., Madasamy, P., Perumal, R., Jagadish, S.V.K. 2020. Quantifying the agronomic performance of new grain sorghum hybrids for enhanced early-stage chilling tolerance. Field Crops Research. 258, 107955.

Li, J., Lin, H., Bean, S.R., Sun, X.S., and Wang, D. 2020. Evaluation of adhesive performance of a mixture of soy, sorghum and canola proteins. Industrial Crops and Products. 157, 112898.

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

Issue: At present, most on-farm systems in Arkansas use either natural or slightly-heated air to dry freshly-harvested, high-moisture content rice and other grains to prevent excessive respiration and mold growth on grains. However, the duration required to achieve drying is greatly affected by weather conditions. The real problem is that the weather may not allow complete drying of the rice, particularly the upper layers, in a timely manner. When this happens, there is a great possibility for mold growth in the grain mass, with potential mycotoxin development, and "quality" deterioration including staining, milling yield reduction, and sensory and functional problems. Mycotoxins, especially aflatoxin, are known carcinogens that pose a severe health hazard to human and animal consumers of grains and co-products. A recently-introduced technology for use in on-farm drying systems, popularly referred to as "cabling technology" offers a means to utilize the advantages of low-temperature, in-bin drying systems, yet prevent the disadvantages that are sometimes incurred with these systems. The new technology controls drying fan operation by the principle of Equilibrium Moisture Content (EMC), which is the moisture content that a specific grain will attain if exposed to air with a given relative humidity and temperature for a long enough duration. Thus, drying fans are operated only under set conditions to avoid over-drying of grain. The new in-bin technology comprises sensors to measure ambient air conditions, as well as cables to monitor grain moisture content and temperature throughout the grain bin mass, and the data can also be accessed anytime via the internet, which has revolutionized monitoring capabilities. From an electronic monitor and fan control standpoint, this new technology appears very promising. However, the ultimate success hinges on accurate EMC data to determine fan run time and knowledge of the rate of mycotoxin development and quality reduction for rice in the upper bin layers.

Response: In collaboration with grain producers, processors and allied scientist and engineers, our researches through lab- and field-based experiments as well simulations and modeling of the EMC-based in-bin drying, sought to answer primary and practical questions that are needed to successfully implement the new in-bin drying systems in Arkansas. These questions included (1) what is the rate of grain "quality" reduction and mycotoxin development under various drying and storage scenarios; (2) with respect to stored product "quality", what is the upper moisture content limit for rice placed into these systems at various geographic locations; and (3) what energy savings could be realized with these new in-bin drying/storage systems? We developed a computer simulation platform capable of predicting natural air in-bin drying of rice using multiple fan running strategies practical for Arkansas conditions. The models used in the simulations were validated using field experiments and in-bin sensors built using newly generated EMC-based mathematical relationships. Charts were generated to document "suitable" in-bin rice drying and storage regimes based on the rice harvest moisture content, rice harvest date, drying air flowrate, and fan control strategy. Advanced engineering, management and optimization of on-farm, in-bin drying, chilling, storage and aeration processes for the high quality and safety of grains. In addition to the forgoing responses the following has been undertaken: develop novel techniques to enhance drying rates while maintaining grain quality, engineer methods for detection, decontamination, and detoxification of harmful-grain molds and mycotoxins, and explore grain and grain processing by-product value addition and utilization.

Outcome/Impacts

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

Publications

Refereed Journal Papers/ Publications [* indicates corresponding author]

Wilson, S., Mohammadi Shad, Z., Oduola, A., Zhou, Z., H. J., Carbonero, F., Atungulu, G. G.*. (2020). Decontamination of Mycotoxigenic Fungi on Shelled Corn Using Selective Infrared Heating Technique. Cereal Chemistry. https://doi.org/10.1002/cche.10394

Luthra, K., Shafiekhani, S., Sadaka, S. S., Atungulu, G. G.*. (2020). Determination of Moisture Sorption Isotherms of Rice and Husk flour Composites. Applied Engineering in Agriculture, 36(6), 859-867. doi: 10.13031/aea.13822

Smith, D. L., Atungulu, G. G.*, Wilson, S., Mohammadi Shad, Z. (2020). Deterrence of Aspergillus Flavus Regrowth and Aflatoxin Accumulation on Shelled Corn Using Infrared Heat Treatments. Applied Engineering in Agriculture, 36(2), 151-158.

Shafiekhani, S., Atungulu, G. G.*. (2020). Effect of rice chilling on drying, milling and quality characteristics. Applied Engineering in Agriculture, 36(5), 767-776. doi: 10.13031/aea.13895

Oduola, A. A., Bowie, R., Wilson, S., Mohammadi Shad, Z., Atungulu, G. G.*. (2020). Impacts of broadband and selected infrared wavelength treatments on inactivation of microbes on rough rice. Journal of Food Safety, 40(2). 10.1111/jfs.12764

Bruce, R. M., Atungulu, G. G.*, Sadaka, S. S. (2020). Impacts of size fractionation, commingling, and drying temperature on physical and pasting properties of broken rice kernels. Cereal Chemistry, 97(2), 256-269. 10.1002/cche.10241

Mohammadi Shad, Z., Atungulu, G. G.*. (2020). Physical Integrity of Long-Grain Hybrid, Pureline, and Medium-Grain Rice Kernels as Affected by Storage Conditions. Applied Engineering in Agriculture, 36(4). doi: 10.13031/aea.13727

Bruce, R. M., Atungulu, G. G.*, Sadaka, S. S. (2020). Physicochemical and functional properties of medium-sized broken rice kernels and their potential in instant rice production. Cereal Chemistry, 97(3), 681-692. 10.1002/cche.10284

Smith, D. L., Atungulu, G. G.*, Mauromoustakos, A. (2020). Processing Parameters for One-Pass Drying of High-Moisture Parboiled Rough Rice with 915 MHz Microwaves. Transactions of the ASABE. doi: 10.13031/trans.14003.

Title

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

By

Ryu, D., University of Idaho

Outputs

Ochratoxin A (OTA) is a possible human carcinogen found in a wide range of foods and agricultural commodities worldwide particularly in cereal grains including oats, wheat and barley. This potent nephrotoxin is of concern because of its thermal stability under most conditions used during food processing and high incidence and concentration in oat-based baby foods. Hence, the effects of added baking soda (0.5% and 1%; w/w), fructose (0.5% and 5%; w/w), or combination of both (baking soda 0.5% + fructose 0.5%; w/w) on the stability of OTA during retorting of porridge type products made of oat flour or rice flour (10% solid content; w/v) were investigated using a laboratory scale horizontal steam retort. The reduction of OTA after retort was 17.2% in oat porridge and 53.8% in rice porridge, while addition of baking soda resulted in greater reduction of OTA. In retorted oat porridge, reduction of OTA was 30.3% and 47.9% with 0.5% and 1.0% of added baking soda, respectively. The reduction of OTA in retorted rice porridge reached 55.5% and 66.4% with 0.5% and 1% baking soda, respectively. Addition of fructose resulted in greater reduction of OTA in oat porridge (35.5-40.8%) but not in rice porridge. The reduction of OTA in retorted rice and oat porridges with combination 0.5% baking soda and 0.5% fructose were 35.8% and 39.8%, respectively. These results suggest that OTA may be reduced significantly by retorting of oat and rice porridge. In addition, added baking soda may contribute to the reduction of OTA in rice and oat porridges while added fructose may facilitate OTA reduction in oat porridge.

Outcomes/Impacts

The effect of a common food processing technique, i.e. retorting, on the ochratoxin A concentrations in contaminated oats was investigated. Retorting was selected as a model system as it is the most common technique to make commercial infant foods.

The reduction of OTA after retort was 17.2% in oat porridge and 53.8% in rice porridge, while addition of baking soda resulted in greater reduction of OTA. In retorted oat porridge, reduction of OTA was 30.3% and 47.9% with 0.5% and 1.0% of added baking soda, respectively. The reduction of OTA in retorted rice porridge reached 55.5% and 66.4% with 0.5% and 1% baking soda, respectively. Addition of fructose resulted in greater reduction of OTA in oat porridge (35.5-40.8%) but not in rice porridge. The reduction of OTA in retorted rice and oat porridges with combination 0.5% baking soda and 0.5% fructose were 35.8% and 39.8%, respectively. These results suggest that OTA may be reduced significantly by retorting of oat and rice porridge. In addition, added baking soda may contribute to the reduction of OTA in rice and oat porridges while added fructose may facilitate OTA reduction in oat porridge.

The Multistate program has provided food industry and general public with a potential measure to ensure food safety by reducing ochratoxin A in cereal-based infant foods during retorting.

Publications

Lee, H.J., C. Lee, and D. Ryu. 2020. Effects of baking soda and fructose in reduction of ochratoxin A in rice and oat porridge during retorting process. Food Control 116:107325.

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

Despite COVID-19 related delays to laboratory work, we have made significant progress data analytics and literature review related to defining skewed distribution of mycotoxins in single corn kernels, methods to classify kernels with those toxins, and laid the foundations for extending this work to Ghana. We have also started to develop practical calibration strategies for single-kernel sorting.

Data analytics and literature review are covered in the 'outcomes' section describing the published work.

To briefly summarize the Ghana work, we worked with in-country collaborators to import nearly 200 lb of corn from Ghana collected from small-scale poultry farming operations. These samples were either stored at proper, low moisture levels or elevated moisture and then dried for shipping. When then imported these samples under appropriate USDA APHIS permits for analysis in our lab.

To briefly summarize our practical calibration strategies, an abstract for the 2020 Annual Meeting of the International Association for Food Protection is as follows:

Introduction: Reflectance spectroscopy at Ultra-Violet, and Near-Infrared wavelengths can detect aflatoxin and fumonisin in corn, but is limited by difficulties present in the identification of sufficient contaminated single kernels to generate calibration algorithms.

Purpose: Test of enrichment for contaminated kernels using a calibrating library of visual high-risk kernels and samples of uncontaminated kernels for classification methods through reflectance spectroscopy.

Methods: From a commercial corn sample (208g), previously tested in bulk >50ppb aflatoxin and >4000ppb fumonisin, kernels were selected according to visual factors associated with mycotoxin contamination and visual characteristics associated with uncontaminated kernels to generate a reject and accept data set, respectively. Kernels were scanned by passing through a LED-ring spectrometer/optical-sorter based on the reflectance values at nine distinct wavelengths (470nm-1550nm), and utilized to calibrate a Linear Discriminant Analysis (LDA) algorithm. Kernels were mixed together and sorted using the optical sorter algorithm. The accepted sorted sample was tested in bulk, while all single kernels from the rejected sorted sample were tested individually (n=192). ELISA kits were used to measure mycotoxins.

Results: LDA algorithm of reject and accept sample yielded a classification specificity of 0.91, and a sensitivity of 0.83. 170g were sorted as accept, and 38g were sorted as reject. The reject sample contained only 1 kernel with aflatoxin (48ppb), while 34 kernels contaminated with fumonisin (<1000ppb), median aflatoxin and fumonisin levels were 0.72ppb and 3801ppm, respectively. Accept sample bulk levels of aflatoxin and fumonisin were below the limits of detection.

Significance: A library of kernels with visual factors associated with mycotoxin contamination can be used to generate sorting algorithms capable of detecting fumonisin contaminated single kernels using spectroscopy.

Outcomes/Impacts

A major impact of this work in the last year was a further the education of an MS student Ruben Chavez. Our group has worked with existing networks in Ghana to import single kernels samples from Ghana for laboratory analysis. In addition, Ruben and Eric have published a literature review on single kernel mycotoxin analysis.
Another major impact is our publication on sample pooling for mycotoxin detection. We feel that as the number of samples necessary to monitor for mycotoxins in grains increases, these pooling methods may be able to significantly reduce analytical costs for labs that are legally able to use these non-standard analytical approaches. All simulation and data analysis code for this paper, as well as the primary data for validation, can be found at https://github.com/ericxbcheng/Pooling.

Publications

X. Cheng, Chavez, R.A., and M. J. Stasiewicz. 2020. When to use one-dimensional, two-dimensional, and Shifted Transversal Design pooling in mycotoxin screening. PLOS ONE. 15(8) E0236668. https://doi.org/10.1371/journal.pone.0236668.

Chavez, R.A., X. Cheng, and M. J. Stasiewicz. 2020. A review of the methodology of analyzing aflatoxin and fumonisin in single corn kernels and the potential impacts of these methods on food security. Foods 9(3). https://doi.org/10.3390/foods9030297

Funding Sources

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

Titles

A Risk Management Approach for Effective Segregation of G.M. and Non-G.M. Grain in Feed Supply Chain.

Development of a Standards-based Traceability System for the U.S. Grain and Feed Supply Chain.

Segregation Strategies for Non-G.M. Corn: Improving Effectiveness Through an Analytical Modeling Approach.

By

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

Outputs

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

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

Cost is an important element in non-GM isolation and segregation. Costs were estimated using Monte Carlo simulation. The analysis focused on costs per bushel for corn and soybeans on the farm and at the grain elevator. Costs at the feed mill were measured by animal species feed by ton (swine, broiler, layer). The analysis measured costs of segregating non-GM feed ingredients and non-GM feed. On the farm, costs to segregate soybeans was estimated at $2.55 per bushel and between $0.52 and $0.58 per bushel for corn. In the grain elevator, costs to segregate soybeans were estimated to be between $1.09 and $1.11 per bushel. Swine feed costs were estimated to range between $15,92 and $16.15 per ton. Poultry broiler feed costs were estimated at between $20.78 and $21.02 per ton, while poultry layer feed costs were estimated to range between $18.88 and $19.11 per ton.

Outcomes/Impacts

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

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

Preliminary interpretations on the costs of segregation suggest that segregation costs are significant, but in years where prices for non-GM mitigate the additional costs of segregated production and handling, the risk level is lower for producers and handlers. In years where the differences between conventional and non-GM feed and feed ingredients are less, the risk will be higher for producers and handlers. The project also confirmed other research that has stated smaller tolerance levels are more expensive and have higher risk of failure throughout the supply chain.

Publications

Sharma, R, C. R. Hurburgh, and G. A. Mosher. 2020. Developing Guidance Templates and Terminology to Support Multiple Traceability Objectives in the Grain Supply Chain. Cereal Chemistry (accepted)

Dolphin, C.J., G.A. Mosher, R.P.K Ambrose, and Ryan, S.J. 2020. Meeting the tolerance: How successful is coexistence in commodity corn handling systems. Applied Engineering in Agriculture, 36(5), 777-784.

Salish, K., G.A. Mosher, and R.P.K. Ambrose. 2020. Developing a Graphical User Interface (GUI) to predict the contamination of GM corn in non-GM corn. Applied Engineering in Agriculture, 36(1), 25-31.

Pizarro, M., E. Bowers, and G. Mosher. 2020. Isolation and segregation of non-GM feed: A cost estimation model. Presentation given virtually at the American Society of Agricultural and Biological Engineers, July 2020.

Sharma, Richa. 2019. Development of a standards-based traceability system for the U.S. grain and feed supply chain. Doctoral Dissertation, Iowa State University, Ames, IA.

Funding Sources

American Feed Industry Association, National Institute of Standards and Technology (Bowers, Hurburgh, and Mosher)

The Andersons Research Grant Program, Team Competition 2016 (Mosher)

N.I.S.T. (Mosher and Hurburgh)

Title

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

B. Development of a Standards-based Traceability System for the U.S. Grain and Feed Supply Chain.

By

Gupta, P., Iowa State University, Graduate Research Assistant, Hurburgh Research Group and I.G.Q.I. Extension Group
Hurburgh, C.R., Professor
Bowers, E., Adjunct Assistant Professor
Mosher, G., Associate Professor
Sharma, R., Former Graduate Research Assistant

Outputs

a. Adventitious presence (AP), i.e., the unintentional or accidental presence of genetically modified (GM) grain within grain lots intended to be nonGM, is becoming an increasing concern for supply chains that wish to produce non-GM animal feed and therefore animals not fed GM ingredients. Management of AP is necessary at every stage to maintain its minimum level in the non-GM feed. A Failure Mode and Effects Analysis (FMEA) was applied to assess the risk of AP in the nonGM feed supply chains for poultry and swine. Over 150 sources of AP from planting to finished feed were identified and evaluated as to probability and severity into a risk score. Risk scores were compounded across the chain (which included both the grain directly to feed and the grain to intermediate processed product to feed options) through statistical simulation to predict the likely mean, high and low contribution of each source.

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

Outcomes/Impacts

a. 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. The impact of this segment of the study is to identify actions that will create AP over acceptable limits, and therefore that should be prioritized in supply chain design.

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

Publications

Sharma, R, C. R. Hurburgh, and G. A. Mosher. 2020 . Developing Guidance Templates and Terminology to Support Multiple Traceability Objectives in the Grain Supply Chain. Cereal Chemistry (acc).

Sharma, Richa, "Development of a standards-based traceability system for the U.S. grain and feed supply chain" (2019). Graduate Theses and Dissertations. 17780. https://lib.dr.iastate.edu/etd/17780

Funding Sources

American Feed Industry Association, National Institute of Standards and Technology

Contacts

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

Richa Sharma, former Graduate Research Assistant, richas@iastate.edu

Title

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

By

Maier, D.E., Professor, Agricultural & Biosystems Engineering, Iowa State University
Obeng-Akrofi, G., Graduate Research Associate, Agricultural & Biosystems Engineering
Brumm, T.J., Associate Professor, Agricultural & Biosystems Engineering
Rosentrater, K.A., Associate Professor, Agricultural & Biosystems Engineering
White, W.S., Associate Professor, Food Science and Human Nutrition
Sonka, S., Associate Graduate Professor, Agricultural and Biosystems Engineering

Research Updates/Outputs

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

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

The first goal of the research is focused on quantifying the loss of shea nuts due to post-harvest handling at the rural production level. This study will form the basis of post-harvest interventions that could be adopted to improve the shea value chain at the rural level. Although a substantial amount of shea nuts is lost after the harvest of shea, little information is known on the quantity and hotspots for these losses in the value chain. This study will apply qualitative research methods where a survey will be carried out in an identified shea producing community in Ghana (as a case study) to determine where these losses are anticipated. The study will also seek to quantify the losses in terms of resources such as time, effort, and money. This quantification will indicate which stages of the value chain need to be given much attention to reducing the loss due to post-harvest handling.

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

The hermetic storage bag technology has proven viable in ensuring food security in many parts of sub-Saharan Africa. The technology has been well adopted by crop producers, mainly cereals and legumes in many sub-Saharan African regions. The efficacy of the technology in reducing grain damage and loss, preserving grain quality, and increasing farmers' profit has been tested and approved by many scientists. Although the hermetic bag system is available at the rural levels, little is known about hermetic bag storage's role in reducing loss, damage and preserving the quality of shea nuts. Therefore, this study will seek to compare the viability of hermetic bag storage of shea nuts to two other conventional storage systems (the use of polypropylene bags and jute sacks) in rural shea growing communities. On November 25, 2020, the storage activity, which will last for six months, was initiated in Ghana. The stored shea nuts will be tested for moisture content variations, insect infestation and damage, and aflatoxin

every six weeks for the storage period. During the storage period, temperature and relative humidity of the ambient and storage condition will be monitored. Also, the CO2 emission in the hermetic bag will be observed every 6-weeks. This study will form the basis for adopting hermetic storage bags to store shea nuts at both rural and commercial levels. A baseline qualitative analysis on the shea nuts is on-going.

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

The ultimate form in which shea nuts are utilized is in the form of shea butter. The butter serves as a fat source in diets and serves as a cosmetic and therapeutic product at the rural level. Storing shea nuts under different storage systems could potentially affect the nutritional quality of the butter processed from the nuts. Shea nuts will be processed by an identified processor to ensure standardization of procedures, using the traditional processing method since this method is widely practiced in rural shea growing communities. Processed shea butter from nuts sampled after six weeks from the second study (using the respective storage treatments) will be analyzed for macronutrients, vitamins, and minerals. Shea nuts samples from the baseline qualitative analysis have been processed into shea butter, and nutritional analyses will be initiated. Besides providing resourceful literature, this study will be informative on the role different storage methods play in the nutritional variability of shea butter.

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

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

Funding Sources

Funding for this study was provided under grants from The Rockefeller Foundation (Grant 2018 FOD 004), the Foundation for Food and Agriculture Research (Grant DFs-18-0000000008), and the Iowa Agriculture and Home Economics Experiment Station.

Publications

Books

Maier, D.E. (editor). Advances in Post-Harvest Management of Cereals and Grains. Burleigh Dodds Science Publishing. https://www.bdschapters.com/webshop/open-access/developments-in-the-use-of-hermetic-bags-for-grain-storage/

Journals

Akowuah, J.O., Maier, D.E., Opit, G., McNeill, S., Amstrong, P., Campabadal, C., Ambrose, K. And Obeng-Akrofi, G., (2018). Drying Temperature Effect on Kernel Damage and Viability of Maize Dried in a Solar Biomass Hybrid Dryer. Open Journal of Applied Sciences, 8, pp.506-517.

Oral Presentations

Obeng-Akrofi, G., Akowuah, J.O., Addo, A., Maier, D.E. Techno-economic analysis of a crossflow column dryer for maize drying in Ghana. 2nd All African Postharvest Congress and Exhibition, Addis Ababa, Ethiopia, September 17-20, 2019.

Akowuah, J.O., Maier, D.E., Opit, G., McNeill, S., Amstrong, P., Campabadal, C., Ambrose, K. and Obeng-Akrofi, G. Modelling the Drying Kintics of Maize Dried in a Solar Biomass Hybrid Dryer. 2019 ASABE Annual International Meeting, Boston, Massachusetts, July 7-10, 2019

Poster Presentations

Obeng-Akrofi, G., Akowuah, J.O., Addo, A., Maier, D.E. Application of the Analytic Hierarchy Process (AHP) in the Selection of an Appropriate Biomass Burner Heat Source for Drying of Maize in a Crossflow Column Dryer. 2019 ASABE Annual International Meeting, Boston, Massachusetts, July 7-10, 2019

Title

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

By

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

Research Updates/Outputs

Monitoring the quality of stored bulk grain is generally done using temperature cables hung from silo roofs. Little investigation has been done into the effects of number of sensors and their placement in terms of reliability of the monitoring system with regard to making stored grain quality management decisions. A previously developed 3D finite element simulation model was verified and used to investigate these aspects. In the first study, a silo was loaded with about 228.6 Mg (9000 bushels) of maize and six temperature cables were placed in the grain mass. The maize was aerated continuously for a period of two weeks, and the cable sensor temperatures were compared to the predicted temperatures which were in close agreement with the observed readings. The standard error of prediction ranged from 2.0 to 3.7°C.

In the second study, 15 and 30 sensors were placed at manufacturer recommended depths and horizontal locations in the grain mass of three silo sizes (i.e., 11x11, 14.6x14.6 and 14.6x18.3 m diameter by eave height). The average grain temperatures predicted by the 15 and 30 sensors over a one-year simulation period were compared to the average grain temperatures predicted for the entire grain mass (1968, 3052, and 3204 mesh nodes). The number of sensors needed to monitor stored grain temperatures reliably in the three silo sizes investigated heavily depended on whether the aeration control strategy achieved a sufficiently low temperature by the time the aeration fans were turned off and sealed ahead of the non-aerated storage period. Fifteen or 30 sensors were sufficient to monitor grain temperatures during the aeration cooling period but for the two larger silo sizes more than 30 sensors would be needed during the storage period. As silo size increased, and surface-to-volume ratio decreased, grain temperatures remained lower during the storage period. Results support the best management practice recommendation of leaving cooled grain cold and not warming it up in the spring ahead of storage into the summer.

Funding Sources

Funding for this study was provided under a grant from The Andersons Research Grant Program Regular Competition 2017

Funds from the Iowa Agriculture and Home Economics Experiment Station.

Publications

Book Chapters

Aby, R.G., & Maier, D.E. 2020. Advances in techniques for monitoring the quality of stored cereal grains. In Advances in postharvest management of cereals and grains (pp. 363-387). Burleigh Dodds Sciences Publishing, Cambridge, UK (ISBN: 978 1 78676 352 5; https://shop.bdspublishing.com/store/bds/detail/workgroup/3-190-89119

Oral Presentations

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.

Poster Presentations

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

Title

Field Testing of P.I.C.S. Bag Maize Storage in Haiti.

By

Mompremier, R.K., Land O'Lakes, Inc., Arden Hills, MN

Bern, C.J., Emeritus University Professor, Agricultural and Biosystems Engineering, Iowa State University
Bowers, E.L., Research Scientist III, Agricultural and Biosystems Engineering
Brumm, T.J., Associate Professor, Agricultural and Biosystems Engineering
Maier, D.E., Professor, Agricultural and Biosystems Engineering

Research Updates/Outputs

Maize is a staple food in Haiti and most Haitian farmers grow maize which they shell and store or sell as a cash crop. Postharvest losses are estimated at 30% and insect damage is a major problem. The PICS bag system is a hermetic storage technology developed at Purdue University to decrease post-harvest losses due to insects in grain stored on smallholder farms and to prevent the development of fungi and mycotoxins. The objective of this research was to determine the value of using PICS bags for long-term on-farm storage of maize in Haiti against post-harvest losses from maize weevil, storage fungi, and aflatoxin production. Two different types of 50-kg storage bags were used: PICS bags and control bags, which were pre-used rice and bean sacks common in Haiti. Experimental bags were loaded with about 50 kg of maize and stored without opening for five months. Initial data taken included moistures, aflatoxin levels and live weevil counts. After the five-month storage period, bags were opened, sampled and the same measurements repeated. Live weevil populations averaged 5 weevils/kg before storage. After storage, PICS bags averaged 0.7 weevils/kg and control bags averaged 199 weevils/kg. Most aflatoxin values were below the 2 ppb limit of quantification before and after storage. PICS bags effectively protected stored maize over 5 months of storage.

Funding Sources

Funding for this study was provided by Dr. Floyd Herum, Ft. Dodge, Iowa, and the Iowa Agriculture and Home Economics Experiment Station.

Publications

Mompremier, R.K. 2020. Field testing of PICS bag maize storage in Haiti. American Society of Agricultural and Biological Engineers K. K. Barnes Undergraduate Student Paper Competition entry.

Title

Mathematical Modeling and Characterization of Grain Mixing and Flow in the Storage Bin.

By

Mosher, G.A., Associate Professor, Agricultural & Biosystems Engineering, Iowa State University
Hurburgh, C.R., Professor, Agricultural & Biosystems Engineering
Tenboer, H.H., Graduate Research Assistant, Agricultural & Biosystems Engineering
Sharma, R., Former Graduate Research Assistant, Agricultural & Biosystems Engineering

Research Updates/Outputs

The goal of this project was to mathematically characterize and model factors influencing the mixing and resulting flow of grain product in a hopper bin. A lab benchtop model was constructed to establish and measure protocols and parameters needed to measure the effectiveness and uncertainty of traceability systems so the values can be used in mathematical blending models.

The model estimated uncertainty and defined performance measures of various handling scenarios. The model was also tested with a case study where a portion of a storage bin's grain was tracked. The model demonstrated that behavior of the grain flow did not change dramatically in the flow characteristics. Thirty trials were completed, with grain removed at three levels: 800 grams, 400 grams, and 200 grams. Ten replications of each trial were completed. The initial model provided validation and a baseline for future research, including the ability to build a probability model to predict the potential of traceability success or failure under selected scenarios.

Funding Sources

N.I.S.T.

Publications

H.H. Tenboer, G.A. Mosher, and C.R. Hurburgh. 2020. A quantitative model to characterize granular flow behavior: A measure of grain layer mixing in storage facilities. ASABE Paper # 2000735. Doi: https://doi.org/10.13031/aim.20

H.H. Tenboer, G.A. Mosher, and C.R. Hurburgh. A quantitative model to characterize granular flow and mixing of grain layers. In process.

H.H. Tenboer. Verification of a quantitative model to characterize granular flow – A measure of mixing of grain layers. M.S. Thesis, Iowa State University, Ames, IA.

Title

Role of Worker Decision Making in Effective F.S.M.A. Implementation.

By

Mosher, G.A., Associate Professor, Agricultural & Biosystems Engineering, Iowa State University
Bowers, E.L., Associate Scientist and Adjunct Assistant Professor, Agricultural & Biosystems Engineering

Research Updates / Outputs

This project examined worker decision-making choices in two quality-oriented grain receiving tasks: the presence of grain with suspected aflatoxin and the receipt of flooded grain. Workers were presented with a hypothetical scenario that asked how they would respond when receiving grain that showed a high likelihood of aflatoxin. Workers were asked to consider several alternatives and justify their decision choice based on selected factors. The decision-making factors were identified through a review of published literature. Approximately three-quarters of workers surveyed indicated they would test suspect grain (or divert grain for testing) if they were serving a sensitive market, but nearly half also said they would not test the grain if the market was not sensitive or if testing and documentation of no toxin presence was not required by future buyers.

In the scenario with flooded grain, workers were presented with a decision-making scenario and relevant factors identified through previous published literature. The power of known networks was suggested as a deterrent to following best practices in this scenario, with only 40% indicating they would treat grain differently after a flood event if they knew the supplier. Workers also stated they would consider grain as potentially flooded if they observed an off odor or appearance, higher than expected moisture content, and dryer damage.

The results from both studies suggest that worker decisions and their resulting actions play an important role in maintaining grain and feed quality and safety. Further, incentives in the form of market pressure from buyers play a role in encouraging positive handling practices when the presence of aflatoxin-contaminated or flood grain is present. Finally, the findings also suggest that reminders of critical-to-quality policies are warranted during harvests where aflatoxin, flooded grain, or other damaging characteristics are present.

Funding Sources

The Andersons Research Grant Program – Regular Competition 2017.

Publications

Bowers, E.L. and Mosher, G.A. Role of worker decision-making in effective FSMA implementation. Prepared for presentation at 2020 NC-213.

Two research manuscripts in progress.

Title

Marketing and Delivery of Quality Grains and BioProcess Coproducts.

By

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

Accomplishments and Impacts

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

Research in 2020 studied the efficacy of food safe repellents for application to food packages or milling and storage structures, and also an evaluation of the fumigant ethanedinitrile, EDN, in place of methyl bromide and phosphine for stored grain pests. Plant-based products and common safe repellents are sometimes suggested for managing stored product insects. Contact toxicity and repellent activity were analyzed for the safe terpenoids carvacrol, citronella oil, geraniol, nootkatone, ocimene and R-(+)-pulegone. The synthetic commercial repellents, N,N-diethyle-metatoluamide (DEET), and the fatty acid mixture of octanoic, nonanoic, and decanoic (C8910) acids were also evaluated. Pests studied were the lesser grain borer, Rhyzopertha dominica and the cigarette beetle, Lasioderma serricorne in controlled laboratory experiments. Carvacrol and R-(+)-pulegone exhibited the highest contact toxicity with LC50 values of 0.019 and 0.023 mg/cm2 against L. serricorne and LC50 values of 0.012 and 0.019 mg/cm2 against R. dominica, respectively. Similarly, C8910, geraniol and citronella oil showed toxic effect against both insects. The repellent activity of compounds was tested using the preference method assay at concentrations ranging between 3.125 and 50.0 µg/cm2. The highest repellency percentage (RP) was achieved by C8910 against L. serrcorne with an RP value of 76.0% at the lowest concentration (6.25 µg/cm2), while carvacrol showed the highest repellent activity against R. dominica with RP value of 88.0% at 3.13 µg/cm2 within 3 h of insect exposure.. The tested compounds caused higher repellent activity to R. dominica than L. serricorne and showed promise for commercial application.

The ban of methyl bromide in the USA and the evolution of resistance to phosphine in many species of grain insects has spurned research on alternative fumigants. Ethanedinitrile (EDN) is one potential alternative as it is commercially available, registered for use in several countries and has potential for application to stored products. Controlled laboratory studies determined that EDN fumigation could give good control to all life stages of the lesser grain borer, R. dominca and the cigarette beetle, L. serricorne. However, EDN is highly sorptive on several commodities with a resulting low gas concentration, which could limit its use on large bulks of commodity while still being useful to fumigate warehouses and manufacturing centers with commodity removed. Lab experiments determined that CO2 at 30% combined with a low dose of EDN exhibited a significant effect on the mortality of all life stages of R. dominica and L. serricorne. Tests in which colonies of both beetles species were fumigated with EDN in chambers with a large amount of wheat grain or flour could avoid loss of EDN concentration from sorption and enhance mortality is CO2 was added to the chamber. Therefore, EDN shows promise as an alternative fumigant, and future studies can address treatment of commercial scale commodities.

We have also developed novel milling flow sheets for processing sorghum on a roller (wheat) mill. The developed mill flow sheets can readily be adopted by the wheat milling industries to mill sorghum without adding any additional equipment to their process.

Publications

Athanassiou, C. G., T. W. Phillips, F. H. Arthur, M. J. Aikins, P. Agrafioti and K. L. Hartzer. 2020. Efficacy of phosphine fumigation for different life stages of Trogoderma inclusum and Dermestes maculatus (Coleoptera: Dermestidae). J. Stored Prod. Res. Vol 86. https://doi.org/10.1016/j.jspr.2019.101556

Hasan, M. M., Athanassiou, C. G., Schilling, M. W., Phillips, T. W. 2020. Biology and management of the red-legged ham beetle, Necrobia rufipes DeGeer (Coleoptera: Cleridae). J. Stored Prod. Res. Vol. 88, https://doi.org/10.1016/j.jspr.2020.101635

Nayak, M. K., G. J. Daglish, T. W. Phillips and P. R. Ebert. 2020. Resistance to the fumigant phosphine and its management in insect pests of stored products: a global perspective. Ann. Rev. Entomol. 65: 333-350.

Ramadan, G. R. M., Abdelgaleil, S. A. M., Shawir, M. S., El-bakary, A. S., Zhu, K. Y., Phillips, T. W. 2020. Terpenoids, DEET and short chain fatty acids as toxicants and repellents for Rhyzopertha dominica (coleoptera: Bostrichidae) and Lasioderma serricorne (Coleoptera: Ptinidae). Vol. 87, https://doi.org/10.1016/j.jspr.2020.101610

Ramadan, G. R. M., K. Y. Zhu, S. A. M. Abdelgaleil, M. S. Shawir, A. S. El-bakary, P. A. Edde, and T. W. Phillips. 2020. Ethanedinitrile as a fumigant for Lasioderma serricorne (Coleoptera: Anobiidae), and Rhyzopertha dominica (Coleoptera: Bostrichidae): toxicity and mode of action. J. Econ. Entomol. Online doi: 10.1093/jee/toz343

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.

Alemayehu, S., F. Abay, K. M. Ayamut, D. Assefa, A. Chala, R. Mahroof, J. Harvey, and Bh. Subramanyam. 2020. Evaluating different hermetic storage technologies to arrest mold growth, prevent mycotoxin accumulation and preserve germination quality of stored chickpea in Ethiopia. Journal of Stored Products Research, 85, 101526. DOI: https://doi.org/10.1016/j.jspr. 2019.101526.

Molla, A., S. Alavi, Bh. Subramanyam, and N. Gabbiye. 2020. Drying characteristics of maize grain in solar bubble dryer. Journal of Food Process Engineering, 43, 13312. DOI: https://doi.org/10.1111/jfpe.13312.

Molla, A., N. Gabbiye, Bh. Subramanyam, M. Admasu, K. Kalsa, and S. Alavi. 2020. Effects of grain drying methods on postharvest insect infestation and physicochemical characteristics of maize grain. Journal of Food Process Engineering 13423. DOI: https://doi.org/10.1111/jfpe.13423.

Anthony, K. D. J., R. Maghirang, D. W. Hagstrum, K. Y. Zhu, and Bh. Subramanyam. 2020. Using dynamic dew point isotherms to determine the optimal storage conditions of inert dust-treated hard red winter wheat. Grain & Oil Science Technology, 06.004. DOI: https://doi.org/10.1016/j.gaost.2020.06.004.

Stamenković, O.S., K. Siliveru, V.B. Veljković, I.B. Banković-Ilić, M.B. Tasić, I.A. Ciampitti, I.G. Đalović, P.M. Mitrović, V.Š. Sikora, P.V.V. Prasad. 2020. Production of biofuels from sorghum. Renewable and Sustainable Energy Reviews, 124: 109769. https://doi.org/10.1016/j.rser.2020.109769

Arthur, F.H., S. R. Bean, D. Smolensky, A. R. Gerken, K. Siliveru, E. D. Scully, and N. Baker. 2020. Development of Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae) on sorghum milling fractions. Journal of Stored Products Research, 87: 101606. https://doi.org/10.1016/j.jspr.2020.101606.

Pezzali, J. G., A. Suprabha Raj, K. Siliveru, and C. G. Aldrich. 2020. Characterization of white and red sorghum flour and their potential use for production of extrudate crisps. PloS One, 15: e0234940. https://doi.org/10.1371/journal. pone.0234940

Title

Modeling of the Temperature Distribution during Bagged Storage.

By

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

Outputs

A two-dimensional finite difference model that predicts the temperature and moisture distribution of corn stored in a stack of woven polypropylene bags in a naturally ventilated warehouse was developed. The model was tested using a stack of 192 bags containing 40 kg of shelled corn. The stack was placed in a ventilated building with no climate control. Temperature and relative humidity were logged with a custom-made system based on Sensirion SHT35 sensors. Monthly samples were taken from bags on the edge to determine moisture content.

Using material properties for bulk corn resulted in very poor model performance. It was hypothesized that thermal properties in a stack of bags and bulk grain would be different. The bulk density of the stack was 570 kg/m3 which was determined using the dimensions of the stack and the weight of corn in the bags. This compares to a bulk density of 730 kg/m3 measured using the Winchester Cup Method.

Thermal diffusivity was calculated from experimentally measured temperature in the bags using an inverse heat transfer method. The relationship between transient heat transfer over a given dimension and the thermal diffusivity was solved using a finite difference approximation. Multiple segments of experimental data over an extended period where the corn temperature continuously changed (increased or decreased) were fitted to the previous equation. Data for a period of at least 60 hours was used in the equation. Thermal diffusivity was calculated using the Goal Seek Add-In (Microsoft Excel, Microsoft Corp., Redmond, WA). Specific heat was assumed to be equivalent for bagged and bulk corn. Thermal diffusivity of bulk corn is approximately 1.22E-6 m2/s while bagged corn was measured as 5.85E-7 m2/s. Subsequently, thermal conductivity was calculated from thermal diffusivity. The thermal conductivity for bulk grain is approximately 1.79 W/m C, but for bagged grain was measured as 0.68 W/m C.

With the modified thermal properties, the predicted temperatures were consistent with the measured temperatures with a mean standard error of 1.1 °C and 0.5 °C in the large and small stack, respectively. Average standard error was 1.6 °C for the bags at the top, 0.8 °C for the middle bags and 1.2 °C the bottom bags. In the small stack, mean standard error was 0.6 °C, 0.5 °C and 0.4 °C for top, middle and bottom bags, respectively. The model can be used to predict temperature distribution in a stack of bagged grain and to determine the required number sensors and appropriate placement for effective monitoring of bagged grain quality during storage.

Outcomes/Impacts

The focus is on the development of sensors and models to measure the quality of stored grain. This could include future incorporation into silo bags and monitoring of other bagged commodities.

Title

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

By

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

Petingco, M., Kansas State University, Manhattan, Kansas

Outputs

Deterioration during storage and handling. High dust concentrations can cause serious problems in grain handling, including health and safety risks from dust inhalation and increased risk of explosions. Dust explosions are one of the most serious and widespread types of explosions that occur in industry. To better understand dust dispersion, it is necessary to understand the formation of dust clouds and the conditions in which grain dust separates from grain. This study improves the understanding of dust generation during grain handling by determining the characteristics of dust adhered to corn kernels.

Five corn samples of varying quality, grade, and harvest year were obtained from farmers and grain processors, with three sources in Indiana and one in Kansas. The total quantity of dust in the corn samples was measured using the washing procedure. Centrifuge method was used to analyze the attachment strength of the dust to the corn kernels.

Large variability of dust content was observed among the corn samples, with this variability extending to samples of the same grade, although qualitative differences were observed between samples. Of the factors tested, only the sample and centrifuge speed interaction factors were statistically significant at a 5% confidence level. The attachment strengths of dust particles corresponding to centrifuge speeds were calculated for each corn sample, with the resulting forces ranging from less than 4.6 × 10-10 N to 2.1 × 10-8 N.

Outcomes/Impacts

Results indicated that a portion of the total grain dust is likely to be detached during any physical handling of corn and that grain handling should not unnecessarily increase the impact velocities of grain kernels to the level that would release the additional quantities of dust that are more strongly attached.

Publications

Plumier, B., Zhao, Y., Casada, M., Maghirang, R. and Ambrose, R. P. K. 2020. Dust content and adhesion characteristics of five corn samples. Transactions of the ASABE. 63(2): 495-499.

Plumier, B., Zhao, Y., Casada, M., Maghirang, R. and Ambrose, R. P. K. 2020. Analysis of corn dust particle properties and how surface roughness influences adhesion. Transactions of the ASABE. 63(5): 1493-1497.

Funding Sources and Amounts

USDA-AFRI

Title

Brewers' Grains Granulation for Carriers of Atoxigenic Fungal Spores.

By:

Wang, Xinruo, Agricultural & Biological Engineering, Purdue University, West Lafayette, Indiana, M.S. Student
Ileleji, Klein, E., Professor & Extension Engineer

Outputs

Aflasafe® is a good, efficient and locally (in Africa) manufactured biocontrol product for aflatoxins in grains and oilseeds like peanuts. The problem with Aflasafe® is the use of an expensive food source, sorghum as a carrier for atoxigenic fungi spores, making Aflasafe® expensive, and therefore limiting its access by smallholder farmers in developing countries, who need to use Aflasafe®. Therefore, there is a need to investigate low-cost, sustainable, and effective carriers for the Aflasafe® product.

The brewers grains used in this study were obtained from a local kraft brewery in Indianapolis, Indiana. Granules were manufactured by wet granulation using a bench-top rotating drum. A number of process conditions using a range of ratios of ground brewers grains and a starch solution were used to determine the best combination of ground brewers grain and the binder. Granules were successfully manufactured and tested for their particle and bulk properties (Figure 2).

Outcomes/Impacts

A methodology for the wet granulation of granules from brewers grains was developed.

Figure 2. Coated and uncoated granules manufactured from brewers grains.

Title

Near Infrared Spectroscopy Utilization in Grains, Cereals and Seeds.

By

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

Outputs

Maize Haploid Classification using Single Kernel Near-Infrared Spectroscopy

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

Increased Animal Digestibility of Soybeans

Soybean is an important source of protein, oil, and high protein meal for animal feed. The majority of phosphorus in the seeds is in the form of phytic acid or phytate (PA) and some inorganic P (Pi). PA is unavailable to animals such as poultry and fish and phytic acid can make some metals nutritionally unavailable. To overcome this problem, the addition of Pi or microbial phytase to animal feed is commonly practiced increasing available P. However, excretion of PA can lead to accumulation of P in soil and water, and the subsequent eutrophication of fresh water and near-coastal seawaters. Mutant seeds have been identified which can potentially reduce these problems as reported by the identification of a low phytate and high phosphate mutant and can increase the nutritional value of soybean meal by increasing its digestibility. This study crossed a mutant with a gene, responsible for oil biosynthesis, from the ironwood plant. This resulted in a soybean line with increased Pi, lower phytate and with high oil and protein. IMPACT: Combining the high oil line with a low phytate-high phosphate mutant resulted in improved soybean seed compositional attributes highly desired for animal nutrition.

Detection of Chlorpyrifos-methyl Insecticide in Rice

Rice is the most consumed staple food by humans, particularly in Asian countries, making it imperative that rice safety is given high priority. The presence of pesticide residues in rice and the possible adverse effects on human health associated with consuming residues represent a major concern. Chlorpyrifos-methyl is a commonly used insecticide used to eradicate insects and weevils in rice grain warehouses and if improperly applied, can have adverse health effects. A rapid technique was developed using a commercial near infrared (NIR) instrument to determine the presence of chlorpyrifos-methyl in bulk rice samples. Five varieties of rough (paddy) rice, free of

pesticides, were processed into rough, brown, and milled rice and treated with varying levels of chlorpyrifos-methyl based on the maximum residue limits (MRL) for each type, rough, brown and milled. MRL limits vary by the type of processing with milled rice being the lowest. Results show that it was possible quantify the amount of residue in all samples and processing type with reasonable accuracy, and to identify samples with high residue amounts from lower amounts. IMPACT: Rapid screening would be possible using a NIR instrument.

Traits of Peas Measured by NIR Spectroscopy

Peas are cool season crop that produces seeds valued for their high protein content. Breeders have produced modern cultivars with most emphasis on total yield while improving quality has received less attention due to the lack of methods to easily and rapidly measure seed quality traits. This study evaluated a near infrared spectroscopy (NIRS) method for the ability to accurately measure single seed weight, protein and oil content. A set 96 diverse pea samples were analyzed using both single seed NIRS and standard lab methods. NIRS measurement of protein and weight were very accurate while oil content measurement could be used for screening purposes. It was also found that pea seed weight was not related to protein or oil content contrary to what others have suggested. IMPACT: The high accuracy of single seed protein and weight estimation by single seed NIRS could be used in the selection of both high protein and high weight peas early in the breeding cycle allowing for faster genetic gain. This would in turn shorten the time that it normally takes to bring new varieties to market.

Publications

Gustin, JL, Frei, UK, Baier, J, Armstrong, P, Lübberstedt, T, Settles, AM. Classification approaches for sorting maize (Zea mays subsp. mays) haploids using single-kernel near-infrared spectroscopy. Plant Breed. 2020; 139: 1103–1112. https://doi.org/10.1111/pbr.12857

Al-Amery, M., Fowler, A., Unrine, J.M., Armstrong, P.R., Maghirang, E.B., Su, K., De Melo, J., Yuan, F., Shu, Q., Hildebrand, D. 2020. Generation and characterization of a soybean line with a Vernonia galamensis diacylglycerol acyltransferase-1 gene and a myo-inositol 1-phosphate synthase knockout mutation. Lipids. 12253. https://doi.org/10.1002/lipd.12253.

Hacisalihoglu, G., Freeman, J., Armstrong, P.R., Seabourn, B.W., Porter, L.D., Settles, A.M. and Gustin, J.L. 2020. Protein, weight, and oil prediction by single-seed near-infrared spectroscopy for selection of seed quality and yield traits in pea (Pisum sativum). J Sci Food Agric, 100: 3488-3497. https://doi.org/10.1002/jsfa.10389

Rodriguez, F.S., Armstrong, P.R., Maghirang, E.B., Yaptenco, K.F., Scully, E.D., Arthur, F.H., Brabec, D.L., Adviento-Borbe, A.A., Suministrado, D.C. 2020. NIR spectroscopy detects chlorpyrifos-methyl pesticide residues in rough, brown, and milled rice. Transactions of the ASABE. 36(6):983-993.

Serson, W., Armstrong, P., Maghirang, E., AL-Bakri, A., Phillips, T., AL-Amery, M., Su, K., Hildebrand, D. 2020. Development of whole and ground seed near-infrared spectroscopy calibrations for oil, protein, moisture, and fatty acids in calibrations of Salvia hispanica. J. Chem. Soc. 97: 3-13.

Funding and Grants

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

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

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

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

Training Industry Professionals for Feed Safety Challenges and F.S.M.A. Compliance.

By

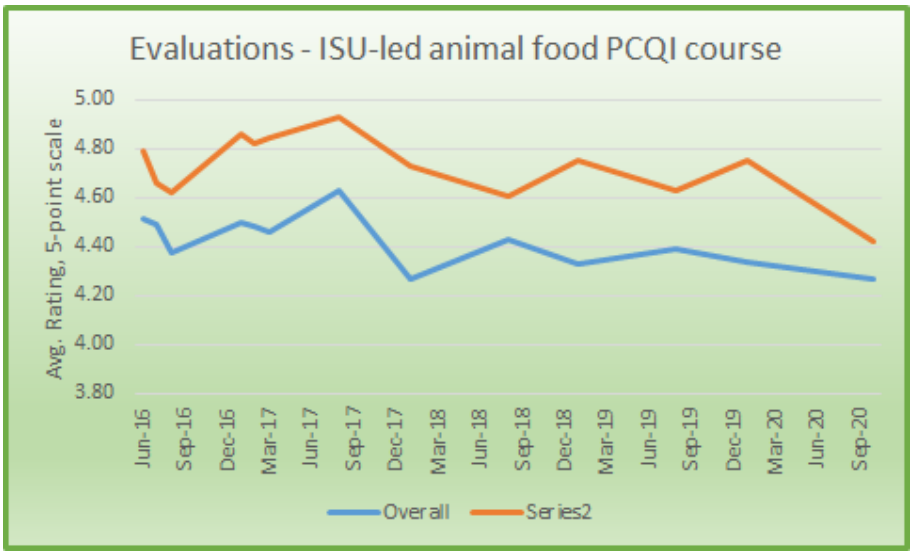
Hurburgh, C.R., Professor, Research Group and I.G.Q.I. Extension Group, Iowa State University
Bowers, E., Adjunct Assistant Professor
Hardy, C., Extension Specialist
Anderson, K., Program Manager

Outputs

We developed an ongoing program for training processing industry professionals in feed safety and associated regulatory compliance using the Food Safety Preventive Controls Alliance (FSPCA) certification materials. Our program was designed to have an industry partner each time the course is taught. Previous industry partners have been Land O Lakes Cooperative, Renewable Fuels Association, and several individual companies in private offerings. Most recently, the American Feed Industry Association has become a consistent partner as we adapted to a real time virtual instructor interactive format for virus management reasons.

Outcomes/Impacts

Since 2016, there have been 13 public open classes training 412 PCQI corporate feed safety professionals and another 4 privately contracted classes. Evaluations on a 5-point scale have been good, and the number of requests for individualized assistance to create Food Safety Plans led us to create a new position specifically for food and feed safety support for companies.



Funding Sources

Self-supported by course fees.

Contacts

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

Title

A Systems Approach to Analyzing and Reducing Post-Harvest Loss (P.H.L.) in Durable and Perishable Food Commodities in Low Income Countries.

By

Maier, D.E., Professor, Agricultural & Biosystems Engineering, Iowa State Univeristy
Chikez, H.B., Graduate Research Associate, Agricultural & Biosystems Engineering
Brumm, T.J., Associate Professor, Agricultural & Biosystems Engineering
Olafsson, S., Associate Professor, Industrial and Manufacturing Systems Engineering
Rosentrater, K.A., Associate Professor, Agricultural & Biosystems Engineering
Sonka, S., Associate Graduate Professor, Agricultural and Biosystems Engineering

Research Updates/Outputs:

Rising incomes in developing countries are driving changes in dietary pattern and increasing the demand for safe and nutritious food. However, to equate future demand and supply of such safe and nutritious agricultural products, global food production will also need to increase. Two commonly documented approaches to increasing production of plant-based agricultural commodities are agricultural intensification and cropland expansion. While both have contributed to a great extent to global food security, they have also shown their limitations specifically with regard to their environmental impact. In light of these limitations, post-harvest loss (PHL) reduction constitutes an important and complementary approach to meeting the increasing demand for agricultural products, but also for increasing profit for food value chain actors, particularly in Sub-Saharan Africa which remains the most food insecure region in the world.

Consequently, this research focuses on analyzing quantitative PHL data obtained from the Rockefeller Foundation, Yieldwise Initiative (YWI) in Kenya, and Tanzania to better understand the impact of various post-harvest technologies in reducing PHL, increasing farmers' income, and controlling the environmental impact in the mango (Kenya) and maize (Tanzania) value chains.

Study 1: Comparing mango post-harvest technologies in Kenya.

This study is the first scientific attempt to quantitatively compare multiple post-harvest technologies and their effects on mango PHL within the Rockefeller Foundation Yieldwise Initiative (YWI) in Kenya. While numerous PHL mitigation studies have been successful at comparing the effects of multiple post-harvest technologies on one specific type of PHL, this study used a systems approach and compared effects on several types of mango PHL. Subsequently, the following results were obtained from analyzing the YWI mango dataset after extensive data screening and cleaning.

1. Post-harvest technologies promoted by the YWI and easily accessible by farmers, such as plastic crates, tarps, and fruit fly traps had the highest adoption. Conversely, post-harvest and pre-harvest technologies promoted by the YWI that were too expensive for farmers, such as harvesting tools and cold stores, had the least adoption.
2. The use of harvesting tools and fruit fly traps is associated with the least ($P<0.05$) mango loss after harvest due to physical damage caused.
3. The use of plastic crates during transportation and cold storage is associated with the smallest ($P<0.05$) mango loss.

Study 2: Predicting the impact of mango post-harvest technologies in Kenya.

As interventions within the YWI were not randomly attributed to farmers, and farmers who benefited from the interventions were not randomly selected either, causal inferences could not be drawn from a statistical comparison of PHL associated with different post-harvest technologies. Therefore, this study focused on predicting the impact of mango post-harvest technologies associated with the smallest PHL to extend the impact of the post-harvest technologies to a broader context. The Random Forest predictive model was used to generate results. Geographic location had overall the highest importance in predicting loss during harvest due to physical damage caused, and losses due to overripe and rotten mangos. The importance of the post-harvest technology factors varied from one type of PHL to another.

Study 3: Life Cycle Assessment (LCA) and Techno-Economic Analysis (TEA) of post-harvest technologies within the mango and maize value chains.

LCA and TEA within the mango value chain to determine the Kg of CO2 emitted per functional unit as well as water usage for each post-harvest technology is on-going. Additionally, costs and profits generated per functional unit of each technology will be calculated. The system boundaries are defined as cradle to use. Following the completion of the LCA and TEA of the mango value chain, another LCA and TEA will be carried out for selected technologies within the maize value chain.

Study 4: Decision support tool for income optimization.

A decision support tool will be developed that will use the acquired knowledge on PHL reduction technologies, environmental impact per technology, and TEA per technology with the primary goal to optimize farmer income.

Funding Sources

Funding for this study was provided under grants from The Rockefeller Foundation (Grant 2018 FOD 004), the Foundation for Food and Agriculture Research (Grant DFs-18-0000000008), and the Iowa Agriculture and Home Economics Experiment Station.

Publications

Book

Maier, D.E. (editor). Advances in Post-Harvest Management of Cereals and Grains. Burleigh Dodds Science Publishing. https://www.bdschapters.com/webshop/open-access/developments-in-the-use-of-hermetic-bags-for-grain-storage/

Oral Presentations

Chikez H.B. and Maier D.E. Analyzing Post-Harvest Loss in Kenya and Tanzania: Lessons learned from the Yieldwise Initiative Data. Consortium for Innovation in Post-Harvest Loss and Food Waste Reduction (Webinar), August 26, 2020.

Chikez H.B., Maier D.E., Olafsson S., and Sonka S. Predicting the impact of various agricultural practices on Post-Harvest Loss (PHL): The case the mango value chain in Kenya. 2020 ASABE Annual International Meeting (Virtual and On Demand), July 13-15, 2020.

Chikez H.B., Maier D.E, and Olafsson S. Predicting and Mitigating Post-Harvest Loss in Sub-Saharan Africa: A System Analysis Approach. 2nd All Africa Postharvest Congress & Exhibition, African Union Headquarters, Addis Ababa, Ethiopia, September 17-20, 2019.

Chikez H.B. and Maier D.E. Initial Analysis of the Rockefeller Foundation Yieldwise Initiative and Actions Moving Forward. The Rockefeller Foundation, New York, December 15, 2018.

Poster Presentations

Chikez H.B. and Rosentrater K.A. Predicting the specific mechanical energy (SME) of a single screw extrusion process. 2020 ASABE Annual International Meeting (Virtual and On Demand), July 13-15, 2020.

Chikez H.B., Maier D.E., and Olafsson S. Predicting and Mitigating Post-Harvest Loss in Sub-Saharan Africa: A System Analysis Approach. 2019 Norman Borlaug Poster Competition, Iowa State University, October 14, 2019.

Chikez H.B., Maier D.E, and Olafsson S. Predicting and Mitigating Post-Harvest Loss in Sub-Saharan Africa: A System Analysis Approach. 2nd All Africa Postharvest Congress & Exhibition, African Union Headquarters, Addis Ababa, Ethiopia, September 20, 2019. – 1st Place Best Research Poster Award.

Chikez H.B. and Maier D.E. Initial Analysis of the Rockefeller Foundation Yieldwise Initiative. 2019 ASABE Annual International Meeting, Boston, Massachusetts, July 7-10, 2019.

Chikez H.B. and Maier D.E. Initial Analysis of the Rockefeller Foundation Yieldwise Initiative. Iowa International Outreach Symposium, Iowa State University, April 14, 2019.

Chikez H.B. and Maier D.E. Initial Analysis of the Rockefeller Foundation Yieldwise Initiative. 2019 NC-213 Annual Meeting, Gateway Hotel and Conference Center, Iowa State University, February 26-27, 2019.

Title

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

By

Maier, D.E., Professor, Agricultural & Biosystems Engineering, Iowa State University
Hurburgh, C.R., Professor, Agricultural & Biosystems Engineering
Bowers, E.L., Associate Scientist III/Adjunct Assistant Professor, Agricultural & Biosystems Engineering
Hardy, C.L., Program Specialist, Value Added Agriculture, Extension and Outreach
Mosher, G.A., Associate Professor, Agricultural & Biosystems Engineering

Outputs

A continuing education course in Advanced Grain Elevator Management was offered in January 2020 with 30 participants. Additional sessions were planned because of high demand, but Pandemic limitations prevented scheduling. The FSMA Preventive Controls Qualified Individual short course continued to be offered 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. Beginning in 2020, the short courses were offered virtually to address Pandemic constraints impacting in-person meetings.

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

Outcomes/Impacts

The Grain Elevator Management course provides professional development for grain industry leadership talent and has been very popular, not only in Iowa but in other Midwestern states. FSMA Preventive Controls Qualified Individual training for Animal Foods continues to have strong demand and work has begun on a course to address more advanced topics.

Funding Sources

Extension funding.
Various other sources.
Pay for service.

Title

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

By

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Outputs

Research projects have been developed and either published, under review, or in progress that directly relate to Objectives 2 and 3. The works "Antixenosis, antibiosis, and potential yield compensatory response in barley cultivars exposed to wheat stem sawfly (Hymenoptera: Cephidae) under field conditions", “Multiple decrement life tables of Cephus cinctus Norton (Hymenoptera: Cephidae) across a set of barley cultivars: The importance of plant defense versus cannibalism” and “Effect of precipitation and temperature on larval survival of Cephus cinctus (Hymenoptera: Cephidae) in barley cultivars” characterize features of pest management that relate to a newly intensifying use of barley by the wheat stem sawfly. Specifically, we consider how cultivar variation can be manipulated into stabilizing yield and quality of barley on the landscape.

There are two key concerns that arise from use of barley by the wheat stem sawfly. Montana is 3rd in production of barley in the US. Significant decreases in yield could have a negative impact on returns for the bulk availability of barley for malt, feed and seed production. Moreover, the potential risk to barley production for the malt industry is likely more grave. The wheat stem sawfly mines stems and impacts vascular flow of nutrients during grain fill. Typically this results in decreased yield in the form of decreased amounts of endosperm – at least in wheat. This causes stable or increased levels of protein relative to carbohydrates. In wheat, this leads to some potential for offsetting loss with a protein premium for wheat marketed in the bread class. Malt barley is more vulnerable because increased protein as a result of loss of “plumpness” is anathema in malt barley. The malt class is met by plump grains with low protein and wheat stem sawfly directly counters this.

Outcomes/Impacts

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

*Bekkerman’s project contributes a study entitled “The Impacts of the Renewable Fuel Standards on Spatial and Vertical Price Relationships in the U.S. Fertilizer Industry”. This article is soon forthcoming in Applied Economics Perspectives and Policy and we will list it as a publication for next year’s report. Dr. Bekkerman will no longer contribute to this multistate effort in his new administrative role at the University of New Hampshire, although we list the above mentioned paper in our 2021 report.

Publications

Achhami, B. B., G. V .P. Reddy, J. D. Sherman, R. K. D. Peterson, and D. K. Weaver. 2020. Effect of precipitation and temperature on larval survival of *Cephus cinctus* (Hymenoptera: Cephidae) in barley cultivars. *Journal of Economic Entomology 113 (4), 1982-1989*.

Achhami, B. B., G. V .P. Reddy, J. D. Sherman, R. K. D. Peterson, and D. K. Weaver. 2020. Multiple decrement life tables of *Cephus cinctus* Norton (Hymenoptera: Cephidae) across a set of barley cultivars: The importance of plant defense versus cannibalism. *PLOS ONE 15 (9), e0238527*.

Achhami, B. B., G. V .P. Reddy, J. D. Sherman, R. K. D. Peterson, and D. K. Weaver. 2020. Antixenosis, antibiosis, and potential yield compensatory response in barley cultivars exposed to wheat stem sawfly (Hymenoptera: Cephidae) under field conditions. *Journal of Insect Science 20 (5), September 2020, 9: 1-14*.