NC-213 PROGRESS REPORT FOR 2025

Title
Standard Method for Assessment and Digital Twin–Enabled Optimization of Hammer Mill Performance

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Outputs/Research Updates
Hammer milling is a critical yet energy-intensive unit operation in feed manufacturing, directly influencing particle size distribution, downstream processing efficiency, feed quality, production cost, and environmental impact. Despite its importance, current hammer milling practice faces two major limitations: (1) A lack of standardized, repeatable methodologies for quantifying performance under steady-state conditions in commercial feed mills, and (2) Limited ability to translate experimental data and operational insights into real-time optimization and effective hands-on training, particularly where access to operating equipment is constrained. This work is significant because it aims to bridge the gap between experimental characterization and operational observation and computational simulation and digital twin enabled process control. The first component establishes a robust, industry-relevant methodology for evaluating steady-state hammer mill performance using power, energy, throughput, and particle size metrics. The second component leverages these validated experimental data to develop a digital twin that integrates CFD–DEM models, real-time sensor data, and AI-based analytics for simulation, optimization, education, and training. By connecting empirical measurement with advanced digital twin technology, this project advances energy-efficient feed manufacturing, Industry 4.0–aligned process optimization, and collaborative engineering and technology education. The integrated framework supports reduced energy use, improved grinding consistency, workforce capacity building, and sustainable modernization of feed mills in both higher and lower income countries. Collectively, this project will establish a scalable, data-driven approach to hammer milling optimization and education, supporting more efficient, sustainable, and technologically advanced feed production systems.

Outcomes/Impacts/Deliverables and updates of studies initiated in 2025

1. *A standardized and repeatable framework for evaluating commercial hammer mill performance under steady-state conditions, suitable for research, industrial diagnostics, and benchmarking.*
   Work has been initiated in the feed mill tower of the ISU Kent Feed Mill & Grain Science Complex (FMGSC) to develop a standardized, repeatable, and industry-relevant framework

for evaluating hammer mill performance under steady-state operating conditions applicable commercially, for research, industrial diagnostics, and benchmarking. Published research on hammer milling was reviewed to identify gaps related to performance and operation of hammer mills, including grinding mechanisms, degree of fine grinding of grains (i.e., corn, sorghum, soybean), particle size reduction and testing procedure, operational automation and control, and design parameters. Based on gaps identified, the framework was developed and validated utilizing ISU's 10 TPH CPM Champion hammer mill and subsequently applying it at a commercial feed mill. The multi-week evaluation focuses on corn grinding performance, utilizing real-time power and energy monitoring, measured throughput, and particle size analysis based on the ANSI/ASAE standard fineness determination method. Two key initial results are the importance of sampling during steady-state hammer milling, and analyzing those samples especially for finer grinds by following the standard method which includes sieve agitators and flow agents.

2. *A validated performance dataset linking throughput, mill load, specific power consumption, specific energy consumption, and particle size distribution to grinding efficacy.*
   Validated performance datasets are being developed utilizing ISU's 10 TPH CPM Champion hammer mill and a 50 TPH CPM Champion hammer mill at a commercial feed manufacturing plant to link throughput, mill load, specific power consumption, specific energy consumption, and particle size distribution (geometric mean diameter and geometric standard deviation) for evaluating the efficacy of hammer mill grinding. These datasets are generated by evaluating steady grinding operation periods under routine production conditions, with an emphasis on identifying steady-state periods. This is defined by a stabilized mill load at the maximum feeder rate during which the hammer mill operates efficiently. This ensures repeatable and comparable assessments of hammer mill performance. Key performance metrics based on literature evidence demonstrate that hammer mill performance is influenced by input material properties (e.g., corn hardness, shape, size) and key design and operational variables, including hammer count and position, aspiration, screen hole size and open area, and hammer tip speed. Collectively, these metrics determine grinding efficacy, energy efficiency, and product consistency.
3. *A functional hammer mill digital twin capable of simulating grain breakage, airflow behavior, energy use, and particle size outcomes under varying operating scenarios.*
   Design parameters of the ISU hammer mill were quantified and entered into CAD software to build the digital twin which was then transferred into EDEM software for animation (i.e., spinning rotor, swinging hammers). Current efforts focus on identifying the physical properties of corn and a model that reflects how corn kernels shatter upon hammer impact. Data was collected on airflow versus static pressure of the ISU hammer mill as a function of throttling the fan of the air assist system. CFD modeling is being utilized to characterize airflow through the hammer mill digital twin. Once coupled and integrated, combined DEM-CFD modeling will enable simulating corn breakage as a function of hammer impact and particle size distribution as a function of airflow pulling particles through the screens under varying operating conditions.
4. *A validated digital twin that can be incorporated into existing plant automation and control platforms to provide for AI-enabled process optimization for improved hammer milling operation in commercial feed mills.*
   To be initiated and reported on in 2026.

5. *An effective virtual training platform that enhances hands-on learning, enables safe experimentation, and improves workforce readiness without reliance on physical equipment access.*
   To be initiated and reported on in 2027.

Publications

Peer-reviewed publications

- Obeng-Akrofi, G., D.E. Maier, K.A. Rosentrater, T.J. Brumm, and J.O. Akowuah. 2025. Evaluation of Moisture Sorption Isotherm for Shea Nuts, *Vitellaria Paradoxa*. Applied Engineering in Agriculture 41:169-178.

Article/News briefs/Reports

- Alexis Lambros, George Obeng-Akrofi and Dirk Maier. 2025. Feed Ops: Importance of steam conditioning. World Grain Magazine. https://www.world-grain.com/articles/21814-feed-ops-importance-of-steam-conditioning
- George Obeng-Akrofi, Younus Bhuiyan Sabbir and Dirk Maier. 2025. Grain Ops: Feed value of corn screenings. World Grain Magazine. https://www.world-grain.com/articles/21962-grain-ops-feed-value-of-corn-screenings

Oral Presentations (Obeng-Akrofi)

- Artificial Intelligence in Feed Manufacturing. AFIA Feed Education Program. IPPE, January 25, 2025. Atlanta, GA (Invited guest speaker)
- Aqua Feed Manufacturing Training Program – Morocco Aqua Industry Team. U.S. Grains and BioProducts Council (USGBC), March 10-12, 2025 (1 tour; 4 hands-on sessions)
- Feed Manufacturing Training Program – Full-Fat Soybean Meal Team. U.S. Soybean Export Council (USSEC) and Iowa Soybean Association, March 25, 2025 (1 lecture; 1 tour)
- Swine Nutrition and Feeding Workshop – Mexico Swine Producers Team. USGBC Mexico Office and Iowa Swine Industry Center, June 3, 2025 (1 lecture)
- IGFIA Advanced Feed Manufacturing & Mill Management Short Course – Southeast Asia Feed Industry Team. USGBC and USSEC South East Asia Region, Iowa Corn Promotion Board and Iowa Soybean Association, July 7-11, 2025 (2 lectures; 7 hands-on sessions)
- IGFIA Advanced Feed Manufacturing & Mill Management Short Course – Tunisia Feed Industry Train-the-Trainer Team. USGBC Middle East & Africa Region, August 18-23, 2025 (1 lecture; 9 hands-on sessions)

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