

NPB FINAL RESEARCH GRANT REPORT

Title: Best Practices in Reducing Feed Waste in Swine Production

NPB project identification number: 22095 PR-005390 grants@pork.org

Eric Weaver, PhD
South Dakota State University

Date: 4/30/2025

Industry Summary: The swine industry is focusing on improvements in environmental stewardship practices with a goal of a 40% reduction in carbon footprint by 2030. Methane release from waste is a large contributor to GHG emissions (Liu et al., 2013). Optimizing feed utilization and efficiency makes progress on the carbon footprint goal possible. Progress on the environmental stewardship goal will add value to pork due to a positive impact on consumer's perception of protein sources. Feed waste is a major contributor to the carbon footprint in production as well as the cost of production. Feed conversion and feed waste are the two most common inefficiencies in feed use. Feed waste as a component of these measures is the most difficult to determine. Without accurate measurement tools for feed waste, a system's feed efficiency, from ingredient purchases to carcass sale weight, is difficult to calculate. The lack of measurement impedes the development of processes for improvement. Yet, progress can be achieved because feed waste is often easy to identify. Likewise, the practices, critical control points, and hazards, contributing to feed waste can also be identified for system-specific plans. The objective of this research project was to: 1) Survey practices in feed delivery and feeder management and processes for management of feed loss or waste; 2) Create a framework/HACCP plan to assess feed waste in each area: grain/ingredient receiving, feed milling, and feed delivery (from mill to pig); 3) Provide a best practices tool to reduce feed waste. Commercial farms or feed mills (n=16) vary in herd size and system type (farrow-finish; wean-finish) were given in-person interviews to obtain survey information on on-farm practices. The participants used phone calls or e-mail for confirmation. The environmental sustainability goal from the NPB was the primary justification for participation. Participation rate was >70% of those invited. The operations queried represented >1.7 million of the estimated 6.0 million head U.S. sow herd represented (Pork Powerhouses, 2024; USDA, 2025). The operations were in the Midwest, Southeast and South-Central U.S. Operation size and ownership varied from corporate, integrated swine operations in the Top 5 largest producers to 500 sow farrow-finish or 2,400 hd wean-finish family-farms. The questions for production systems collected information on the characteristics of the operation, and practices for feed delivery, feed system, feeders and feeding practices, end-of-group practices, feed conversion, feed composition, health, estimates of loss, and greatest focus for preventing loss. The questions for feed transportation, delivery, and excess feed overlapped for mills, transportation, and farm. The questions for mills collected information on practices for ingredient handling and storage, feed production (grinding, mixing, and/or pelleting), and feed unloading. The

survey included questions to identify potential hazards and critical control points for farm, feed transportation, and mill operations. The identification of best practices was based on responses, and the alignment of the response with estimates of feed waste for the respective hazard. Except for the shrink observed at toll and commercial mills, which was estimated from consistent measurement of inventory and feed processed, it was notable that feed waste at critical control points is not consistently reported, and visual estimates are the most common measurement tool (Figure(s) 1 and 2). The estimated feed loss from feed mills, loading to unloading of feed, and at the production farm, were 0-2%, 0-2% and 4-6% respectively. On the basis loss of feed estimates from mill shrink, transportation loss, and farm loss, the total loss is 6-8%. An additional 1.5%-2.0% of feed waste is due to increases in mortality in the past 10 years. Specific production systems that regularly assess critical control points and hazards at the farm report 2-4% total feed waste. 14/16 respondents “Completely Agree” that reducing feed loss is important in swine production. The areas on farms receiving the most focus were daily attention to feeder adjustments and reducing mortality. Operations give less focus to assurance of accurate deliveries, preventative maintenance of the feed system, management of end of group feed, and feed form. Farms consistently report major feed loss events (spills of >1 T per group) even though they are unusual events (Figure 3.). Major inventory inconsistencies, between purchases and ingredient use, and ingredient damage were most common losses in mills. Personnel are a critical factor to feed management from mill to pig. Training, experience and responsibility of all employees and management levels are all important to minimizing feed waste. A major opportunity to reduce feed waste in swine operations is to develop a system for reporting feed waste events. Technology tools such as sensors, machine learning, and AI promise to bring better quantification of feed waste for life-cycle assessments. Pork producers presently can reduce direct feed waste by developing and using training tools for farm staff, truck drivers, and mill operations, equipment preventative maintenance programs, allowing for sufficient time to follow best practices and by reducing mortality.

Key Findings:

- Intentional management and control of processes to minimize feed loss is the highest-order factor in reducing feed waste. Swine farms do not record or estimate feed waste.
- Training, experience, and sufficient time to execute tasks at all three levels (mill, transportation, and farm) is necessary to control causes of feed waste.
- Critical control points of direct feed waste occur at inventory and delivery of ingredients, loading, delivery, filling feeders, end of group management, and daily feeder management.
- Feed waste and feed efficiency are difficult to measure and best addressed with technology tools (sensors, machine learning, AI).
- While CCP’s are critical to manage, >100 significant steps contribute to feed waste management.
- A trend for higher mortality from wean to market will hamper the industry’s sustainability efforts.

Keywords: feed waste, feed spills, feed efficiency, sustainability, swine production.

Abstract: This should be a scientific description limited to one page in length to describe your project and its results.

Introduction: Feed waste in swine production has a significant impact on both economic and environmental sustainability. As one of the largest expenses in pig farming, feed represents a substantial portion of production costs (Carr, 2008). Feed waste estimates can be as high as 5-10%. The pork industry has made it their mission to improve sustainability. One goal the pork industry has alluded to is to reduce greenhouse gas emissions (GHG) by 40% by 2030 (Burr, 2024). Addressing feed waste will help the pork industry to achieve sustainability goals. The development and implementation of practices that aim to reduce feed waste is a current action the industry can take in achieving sustainability.

Objectives: To identify and quantify prevalent sources of system feed loss; to develop tools to audit feed waste for farms, transportation, and mills; to determine the impact of implementing best practices in feed loss management on waste reduction.

Materials & Methods: Production systems and individuals with a working knowledge of the system and feed management were identified on the basis of operation size (numbers of pigs or feed tonnage), location (predominantly Midwest), farm operation type (farrow-finish, or wean-grow-finish; contract or independent growers), feed operations (self-owned, toll, or retail). Animal numbers (>15% of the U.S. industry), type of operation (large corporate to independent farms <1,000 sows farrow-finish) were consistent with production system demographics. Feed tonnage (range of <1000 T per month to >20,000 T per month), location (Midwest to Southeast), and business type (corporate, farm-owned, toll or retail) were representative of feed milling operations for the swine industry. In-person surveys of to capture practices in feed manufacturing, feed transportation/delivery and feed system management (attached in Appendix). The survey information was confidential. Survey participants were employees or owners of commercial farms or feed mills (n=16) varying in herd size and system type (farrow-finish; wean-finish) and feed tonnage. The in-person interviews provided information related to on-farm and/or feed manufacturing and delivery practices. Participants agreed to provide information to the best of their knowledge, and requests were made by phone call or e-mail. The environmental sustainability goal from the NPB was the primary justification for participation. Participation rate was >70% of those invited. The operations queried represented >1.7 million of the estimated 6.0 million head U.S. sow herd represented (Pork Powerhouses, 2024; USDA, 2025). The operations were in the Midwest, Southeast and South-Central U.S. Operation size and ownership varied from corporate, integrated swine operations in the Top 5 largest producers to 500 sow farrow-finish or 2,400 head wean-finish family-farms. The survey questions provided data related to the business operation, specifically excluding respondent opinions, attitudes, or concerns. The survey questions consisted of multi-select, yes/no, fill-in, multiple choice, and open-ended questions. When necessary, the interviewer gave assistance in the interview to clarify questions. The survey requests were by phone call, e-mail, and text messaging. The interviewers gave the surveys in-person, face-to-face or on-line. (n=16) The questions for production systems collected information on the characteristics of the operation, and practices for feed delivery, feed system, feeders and feeding practices, end-of-group practices, feed conversion, feed composition, health, estimates of loss, and greatest focus for preventing loss. The questions for feed transportation, delivery, and excess feed overlapped for mills, transportation, and farm. The

questions for mills collected information on practices for ingredient handling and storage, feed production (grinding, mixing, and/or pelleting), and feed unloading. The survey utilized questions to identify potential hazards and critical control points for farm, feed transportation, and mill operations using the seven principles of HACCP as a framework (USDA, 2020). Identification of a hazard for feed waste occurred with confirmation of a factor, process, or practice by respondents. If many of the respondents indicate a specific step where control measures can prevent, eliminate, or reduce feed waste, the step is a critical control point. The identification of the best practices was based on responses to questions with lower estimates of feed waste for the respective hazard and more than 80% of the respondents with practices in place to address the CCP. The analysis of the survey data utilized Microsoft Excel. The data analysis only used known responses.

Results:

An Overview of the System and Feed Waste

Overall, 14/15 respondents “Completely Agree” that lower feed loss is possible. The estimated feed loss from feed mills, loading to unloading of feed, and at the production farm, were 0-2%, 0-2% and 4-6% respectively. A total loss of feed in swine production, which includes mill shrink, transportation loss, and farm loss, can be estimated to be 6-8%, or 8-10% when including above average wean-finish mortality. Specific production systems that regularly assess critical control points and hazards at the farm report 2-4% total feed waste.

The major hazards for feed waste or inefficient feed utilization are provided in Figures 4-9. The active management of the hazard by most respondents led to the identification of it as a critical control point. Examples include: 6/7 operations responded that they consistently monitor the particle size of corn, whereas only 1/7 of the operations did not. Farms consistently identified major feed loss events (spills of >1 T per group) even though the events were rare. Major inventory inconsistencies and ingredient damage at mills are the major sources of waste. The lack of reporting of feed waste events by all respondents is an important missing step towards a progress goal.

The survey results use n=# if multi-selection questions were available and a fractional response (X/X) when there were limits for selections or a lack of and unknown responses.

Feed Mills Have Fewer Hazards, CCP’s and Estimate Less Feed Waste

Survey questions pertaining specifically to feed mills represented self-owned mills (integrated, n=7 and producer, n=3), toll-mill (n=3) and retail feed operations (n=2). The main feed forms provided for these respondents were mash (n=11), pellets (n=2) and both forms (n=3). The hours of operation were weekdays 6 a.m. to 9:00 pm (n=8) or 24 hrs for 5 (n=1) or 7 days per week (n=6). Mills receive feed orders from on-farm managers (n=10) and logistics teams (n=3). Two on-farm mill managers monitor bins without farm assistance. The order volume is determined by visual inspection (13/16) and/or manual tapping of bins for inventory. One system utilized bin sensors. In feed mills, operators use visual inspection of ingredient bins (6/8), manual contact (5/8), and/or electronic sensors (3/8) for inventory. Visual estimates of bin inventory are still most common on farms and in mills (Figure 1 and 2). In placing feed orders, 8/15 systems primarily use direct electronic systems or apps, and 7/15 systems use phone and/or text. Mill operations monitor grain particle size on a routine basis (weekly or daily). 8/8 feed mills estimate 0-2% feed waste in the mill. In regard to technology, mills utilize (or plan to use) sensors, machine learning and systems technology to reduce feed waste. 2/3 toll mills indicated adoption of technology is important to their future business.

Feed Waste Hazards, CCP's and Best Practices in Delivery and Transportation

Spills in loading the truck occur but the event is infrequent. (Provided by respondent feedback). 12/15 respondents indicate feed spills occur with feed unloading at farms (Figure 3.) and a common amount as < 10 lbs. Two operations reported large feed spills, > 1 T. 2/3 operations reported no spills of significance, all of which were producer, retail, and toll mills. Physical receipts/load tickets is the primary confirmation of feed quantity for 7/14 respondents, 5/14 use both physical and electronic, and 2/14 only use electronic/apps. 10/16 verify the quantity of feed received matched the order, 6/16 do not verify the quantity received. 5/6 confirmed either by visual, truck weights or bin scales.

Standard procedures for feed left in a truck or feed bin at the end of a group are (first choice to last): 1) stays in the bin (n=4); 2) moves to an empty bin on site, n=5); 3) removed and moved to a new site/bin, n=6. The last choices are land-fill disposal (n=1) and return to mill (n=1).

Farm Management:

Surveys of on-farm practices required active, on-farm involvement. 9/9 interviews use automated feeding systems with tandem bins being most common. 6/8 responded that the lids on their bins always function properly, whereas 2/8 responded that the lids on their bins do not always function properly. 5/9 responded that there is feed loss from their bin, hopper, or auger line, whereas 4/9 responded that there is no loss from them. 8/8 responded that the feed fails to flow on various occasions.

Feed inventory is determined by manual assessments (contacting the bin) in 8/16 systems, calculated by computer software in 4/16 with a frequency of 2 or 3 times per week (8/16), daily (5/16) or weekly (2/16). Farm and mill respondents noted that out-of-feed events occur regularly, but it is site dependent.

Feed Delivery: 8/9 responded that the on-farm manager placed the feed order, whereas 1 responded that logistics and the on-farm manager place the feed order. 9/9 responded that feed delivery is in a timely manner, as expected by their operation. 8/9 responded that spilled feed results when unloading. 6/9 farms verify the quantity of feed received 3/9 do not verify.

Inside Barn: 7/9 responded they use automated feed system controls and 2/2 responded they use both automated and manual feed system controls. 4/8 responded that their connection lines leak and 4/8 responded that they do not leak. 6/9 responded that over spills have occurred. 3/9 responded that a major spill had occurred. The auger systems have an over run feature for 5/7 respondents. Repairing line or connections were immediate in 1/8 respondents, 4/8 were less than 24 hrs, and 3/8 responded >24 hrs or when time permits.

Feeders: 8/9 responded that feeder adjustments occur after a daily observation in wean-to-finish, whereas 1/9 responded that feeder adjustments occur weekly. 8/9 responded that 25-50% was their goal for pan coverage for dry feeders in pigs 50 lbs to market weight and 1/9 responded that 50-75% was their goal. 7/8 responded that feeder adjustments fail, resulting in spillage, and 1/9 responded that feeder adjustments did not fail. Sow farms do drop gestation feed to the floor (3/6).

Farrowing: Feed in farrowing is left-over in 3/6 systems and feeders cleaned up in 3/6. 3 respondents indicated that feed removal from feeders, either daily or 2+ days in farrowing. Residual feed disposal goes into pits (3/3). Respondents indicate that pigs in nurseries are gruel or mat fed (7/7). Residual feed in bins or feeders is manual recorded in 3/9 operations.

Feed Conversion: 7/9 responded the use of an adjusted feed conversion in their system; 6/7 respondents use feed conversion adjustments for mortality and 1/7 responded it does not. PRRS, Influenza, and mycoplasma were all diseases thought to affect performance and feed conversion.

Quantity: 8/16 completely agree that reducing feed waste is possible, whereas 6/16 somewhat agree, 1/16 are indifferent, and 1/16 somewhat disagree. 4/8 farms responded that their estimated feed/waste loss in their operation is 0-2%, 3/8 estimated 2-4%, and 2/8 estimated 4-6%.

A summary of responses to one of the final questions is below:

“Please rank these 1-6 with 1 being the greatest focus of the operation in reducing feed waste:

2.7 - Assuring and auditing accurate feed deliveries.

1.3 - Preventative maintenance of feed system.

3.8 - Regular attention and training on feeder adjustments and controls.

4.3 - Management of end of group excess feed.

2.8 – Improving communication and execution (Mill only)

X - Feed form – use of pellets (Producer only)

X - Reducing mortality – adjusting feed records. (Producer only)

Discussion:

The HACCP framework was a collaborative development to produce safe food for the US space program. One of the safety issues in the space capsule under zero gravity conditions was crumbs getting into electrical equipment (Lachance, 1997). Similarly, the application of the seven HACCP principles to the important concern of reducing or preventing feed waste for sustainable pork production is helpful. The interview and survey process in this study yielded >100 key areas in feed management rising to the level of critical control points. We identified the best practices in reducing feed waste by tracing sources of feed waste back to root causes. Recurring root causes led to three highest order factors for best practices in reducing feed waste.

The most important – highest order - factors in minimizing feed waste or loss are intentional management, local knowledge, and ability to control processes. HACCP training includes all staff in the management process. The systems with the highest level of detail on feed waste were very intentional with responsibilities and accountability for feed management. In swine production, not all the staff are aware of feed conversion or feed waste targets, even those involved daily in feed management. Awareness is an essential part of achieving a successful outcome, low incidences of feed waste. Staff with the training, experience, and sufficient time to execute tasks at all three levels (mill, transportation, and farm) best controls the hazards that contribute to feed waste.

Another one of the highest order factors is closeness, i.e., local control, to the operation. Feed mills, particularly those with a toll/retail/ customer focus, are an example of having local control due to the importance of minimizing losses and the direct impact on their business. Inefficient conversion of ingredients or spills at the farm sites could cause a monetary loss and/or potential loss of a customer. Likewise, on-farm mills with communication between farm personnel and mill personnel prevent and manage feed waste. An example of

local control is the management of end of group feed orders and inventory. The survey question regarding the group end “feed left in bins” for systems not near the mill or the farm are less stringent versus those who are owner-operators. The producers with local control and ownership of on-farm and in-barn practices reported the most control over feed management practices and feed waste.

The capabilities and ability to control processes differ significantly amongst mills and farms. Using measurement tools, such as scales, sensors, or software, for actual weights or control of jog time on augers is gaining attention with toll mills or farms adopting innovative technologies as a replacement for the most common measure, visual estimates (Figure 1.).

The major limitation of this study and the determination of best practices is that actual feed waste is both not recorded and/or difficult to assess. Except for the shrink observed at toll and commercial mills, which was estimated from inventory and feed processing inventory, it was notable that feed waste at critical control points is not consistently reported nor quantified with any measurement tools in any other area, which breaks the HACCP principle of “Establish record-keeping procedures”. Feed spilled from a bin, left in bins, or feed left in a feeder is visible and easy to record, but feed due to feed adjustments is not. Respondents may underestimate the percentage of feed loss.

Feed efficiency is a benchmark for swine operations often synonymous with feed waste. The survey revealed that communication of results and potential factors contributing to variance in feed conversion between mill, transportation and farm is not common. Critical factors in calculating and benchmarking feed conversion is whether the farm such as adjustment for body weight and mortality and dietary energy is not known by all staff. With one exception, operations adjust feed conversion for mortality. Mortality is rightfully a source of feed waste, contributing 6 to 12 lbs of feed loss per hd, or 1-2% with an average wean-finish mortality of 7% . Apart from a few instances, mortality is trending higher in swine operations in the U.S. since 2010 (MetaFarms, 2024) which will challenge progress on sustainability goals. Feed waste and feed efficiency are difficult to measure without audited feed deliveries and technology tools may aid producers in this effort (sensors, machine learning, AI).

Management focus is highly variable across the feed management systems. The areas on farms receiving the most focus were daily attention to feeder adjustments and reducing mortality. A lesser focus was given to assurance of accurate deliveries, preventative maintenance of the feed system, management of end of group feed, and feed form. In mills, preventative maintenance of bins/legs/systems is the highest priority, followed by audits of deliveries, and communication and execution.

Processes for management of feed loss or waste: 2) Create a framework/HACCP Plan to assess feed waste in each areas: grain/ingredient receiving, feed milling, and feed delivery (from mill to pig); 3) Provide a best practices tool in consideration of farm SOP's to reduce feed waste.

Critical control points (CCP) of direct feed waste occur at inventory and delivery of ingredients, loading, delivery, filling feeders, and daily feeder management. The methods of assessment of inventory, to calculate waste or loss, is a critical control point. Intentional management of feed waste in feed mills by respondents contributes to the lowest estimated level of feed waste in the three areas of feed management. Feed mills confirm ingredient deliveries but feed delivery verification on farms occurs only by load tickets. If the load does not fit in the tandem bins, verifying the quantity moved and delivered to others is a CCP. The best practice is daily measurements of

inventory and accurate assessments of deliveries and movements of feed on the farm, a common mill practice. Without accurate inventories and audited deliveries, feed use (in calculation of feed efficiency) is a highly variable measurement and not in determining feed waste. Feeder adjustments are an example of an ability to control processes. Daily attention to feeder adjustments is a hazard, a critical control point, and a best practice in reducing feed waste. But the ability - available time and training – of the system to achieve is a challenge on farms due to the availability of labor. Visible and manual methods of assessing feed inventory can improve with technologies such as sensors, AI and machine learning. These technologies promise to provide real-time data which will assist all personnel in assessing % feed waste.

The major finding of this research is recognition of the need for systems to capture feed waste data and the importance of intentional management. From the surveys and comments, diagrams were developed to trace feedback sources back to root causes of feed waste in different areas (Figures 4, 5, and 6). These diagrams can be used to develop the best relevant practices for each operation. The managers and operations in the feed mill, in transportation, and on the farm play a vital role in identification of major root causes of feed waste in operations. While these diagrams for root causes are not comprehensive, their utilization in the design of either large or small systems SOP's for preventing feed waste, may capture areas previously not considered. Achieving gains in feed efficiency and preventing feed waste for systems is a sum of small improvements and elimination of variance in a complex system.

In summary, while actual system feed waste is difficult to estimate, identification and management of the potential sources will reduce errors in the system and prevent feed waste. Reporting and recording feed waste from sources is one of the most important practices in preventing feed waste and to making greater progress in pork sustainability. Adoption of HACCP principles for feed waste will save the industry money and make it more sustainable.

Figure 1. Common methods used in monitoring feed or ingredient inventory.

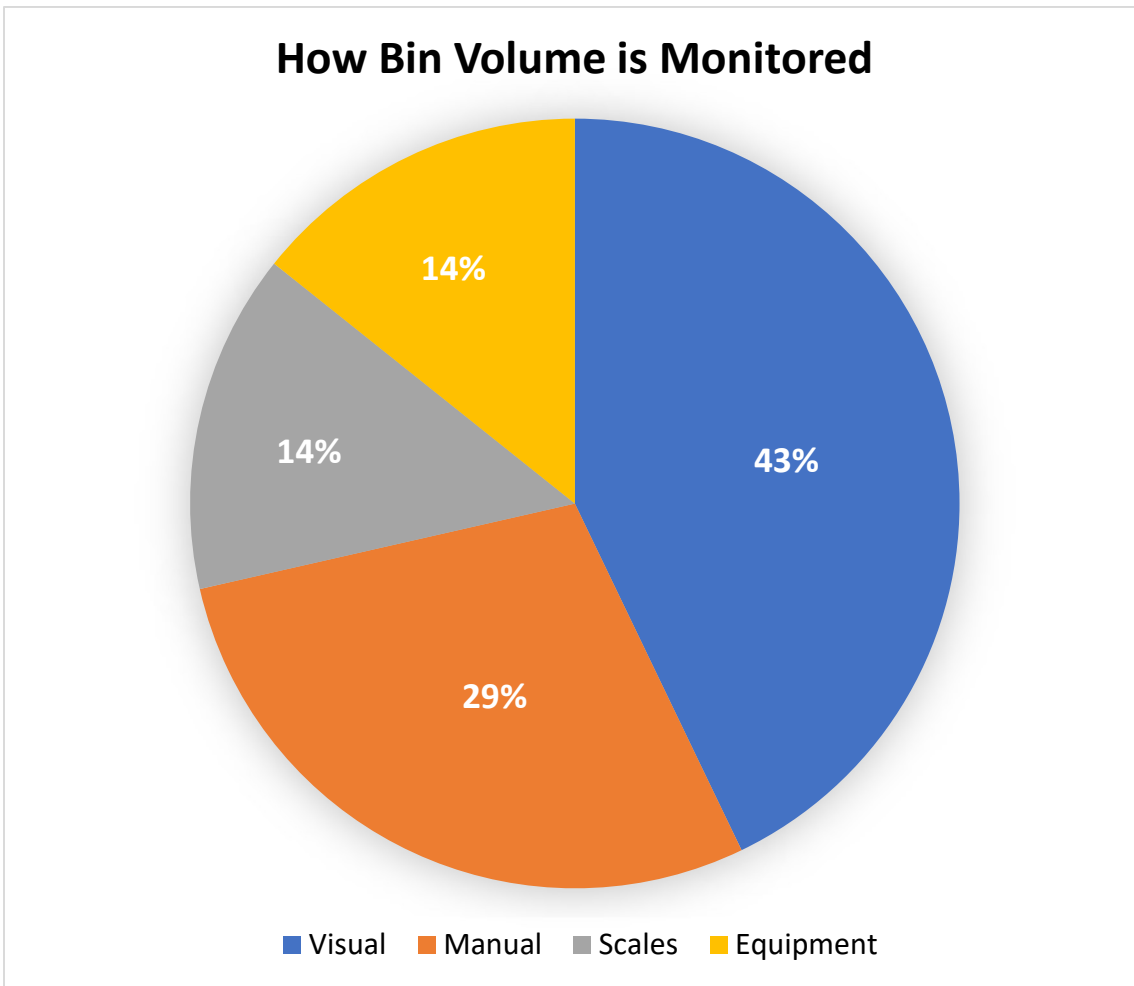


Figure 2. Common methods used in confirming feed delivery.

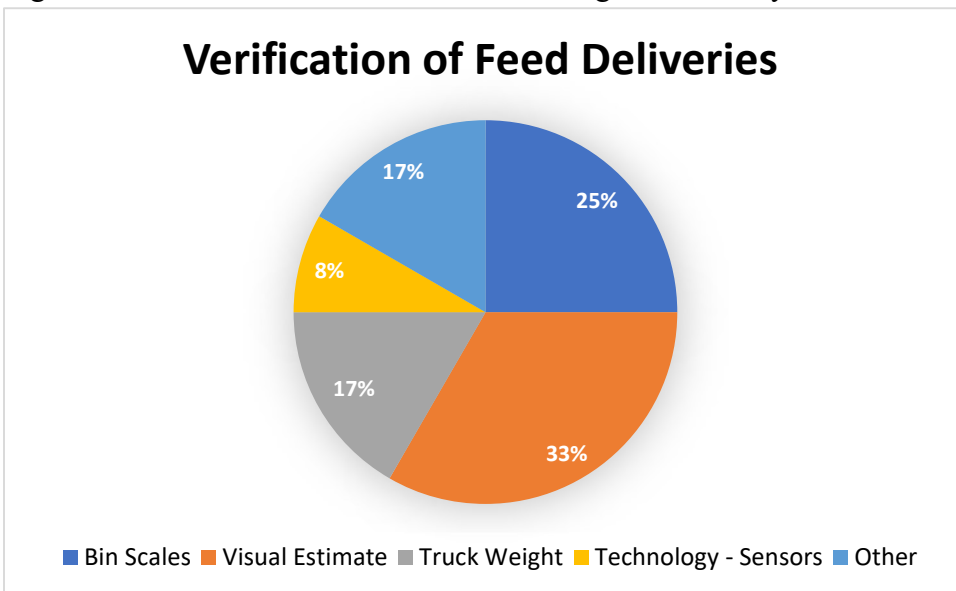
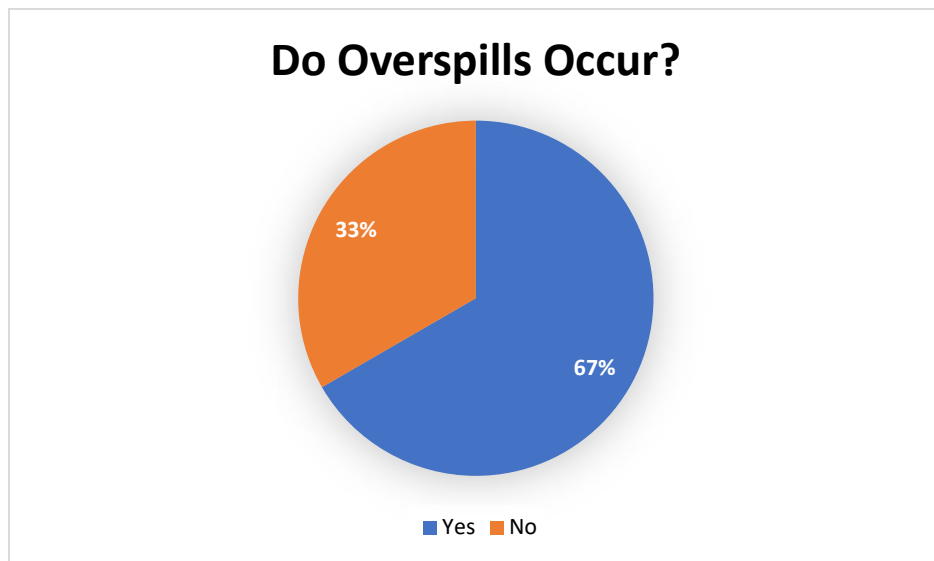


Figure 3. Reporting of feed spills in mills and on farms



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Appendix (Resources upon request)

Survey versions

Fig. 4 [Waste in the feed mill diagram v2](#)

Fig. 5 [Waste during transport diagram v2](#)

Fig. 6 [Waste in farm feeding systems v2](#)