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Abstract

To help meet the production gap of a growing population, the agricultural industry is incorporating new quality management practices to improve operational efficiency. In the agricultural supply chain, operations management within the grain handling industry represents an important area for quality management improvement to meet the growing needs for food safety and security. The strong growth in the use of quality management systems in agricultural environments reflects interest from the production agricultural industry. The present case study examines the impact of implementing a quality management system at a large, multi-site grain elevator company by comparing selected quality metrics before and after QMS adoption. After adoption, the company statistically reduced the grain quality measurement error in grading damage and foreign material, resulting in significantly greater value to shipped grain. The company was also able to add monetary value to low-value grain by using quality metrics to optimize their inventory management and blending strategy. Significant gains were not made in all areas examined, but generally, quality management systems added internal efficiencies and provided a means of adding value to low-quality grains within the grain elevator studied.

Keywords

Grain, Management, Postharvest treatment, Quality, Quality controls

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Comments

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APPLICATION OF QUALITY MANAGEMENT SYSTEMS TO GRAIN HANDLING: AN INVENTORY MANAGEMENT CASE STUDY

C. M. Laux, G. A. Mosher, C. R. Hurburgh

ABSTRACT. *To help meet the production gap of a growing population, the agricultural industry is incorporating new quality management practices to improve operational efficiency. In the agricultural supply chain, operations management within the grain handling industry represents an important area for quality management improvement to meet the growing needs for food safety and security. The strong growth in the use of quality management systems in agricultural environments reflects interest from the production agricultural industry. The present case study examines the impact of implementing a quality management system at a large, multi-site grain elevator company by comparing selected quality metrics before and after QMS adoption. After adoption, the company statistically reduced the grain quality measurement error in grading damage and foreign material, resulting in significantly greater value to shipped grain. The company was also able to add monetary value to low-value grain by using quality metrics to optimize their inventory management and blending strategy. Significant gains were not made in all areas examined, but generally, quality management systems added internal efficiencies and provided a means of adding value to low-quality grains within the grain elevator studied.*

Keywords. *Grain, Management, Postharvest treatment, Quality, Quality controls.*

The changing legislative, environmental, and economic climate has introduced new challenges and opportunities to the grain handling industry. The needs of a growing population and a marginal increase in farmland require great improvements in production efficiency for food security (FAO, 2013). Production efficiency involves a more effective use of existing resources to meet the food security needs of the planet (Flynn and Flynn, 2005). The benefits of improved food security also flow back on the food supply chain, demanding better management of resources to capture greater value for companies operating in the food and foodstuff supply chain. Production efficiency is the result of improved use of existing resources while still meeting customer demands (Flynn and Flynn, 2005). The needs of agriculture require comprehensive and systematic solutions (FAO, 2013). The application of quality principles, organized through the adoption of quality management systems (QMS), can potentially provide systematic solutions.

This case study utilized internal data from a multi-location grain handling company to measure product and process quality before and after QMS adoption. The goal was to understand how a QMS operating in a commodity operation improved operational efficiency and added financial value. Operational efficiency is generally measured in relative terms (i.e., more efficient or less efficient) rather than in absolute terms and is defined in this article as a relationship between results achieved and resources used. The research objective was to examine existing data on grain quality to add value to grain in both the grading and shipping processes. Quality management systems were applied to the challenge of adding value to grain products in a low margin, mature industry.

LITERATURE REVIEW

QUALITY MANAGEMENT SYSTEMS IN AGRICULTURE

Use of quality management systems (QMS) has become a predominant trend in many industries including manufacturing, healthcare, and service. A QMS is the collection of coordinated activities that directs organizational policy to meet or exceed customer expectations (ISO, 2008). Accreditation or certification by independent auditing bodies may be accomplished if the QMS meets published standards.

The most predominant standards body, the International Organization for Standards (ISO), publishes over 14,000 international standards, including QMS standard, series ISO 9000 (ISO, 2013). Released in 1987, the ISO 9001 quality standard is the most widely adopted standard worldwide with over 1 million certifications issued (ISO, 2013). ISO 9000 series was derived, in part, from national requirements, such as British Standards (BSI) 5750 quality assurance standards and has been revised three times since its 1987 release (Zaibet and Brendahl, 1997). The most

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recent update to ISO 9000 was completed in 2008 (ISO, 2013).

More specific to the agriculture sector are other QMS, such as the American Institute of Baking's (AIB) Quality System Evaluation (QSE). Similar but less comprehensive than ISO, the AIB standard has common elements with ISO 9001 such as: documentation; self audits, management responsibilities, product control, and measurement verification (Stevenson, 2004). In this study, with concepts and accompanying language more familiar to the grain handling industry, implementing a quality management system was a good intermediate step toward ISO certification (AIB, 2014; Sullivan and Hurburgh, 2002). The mission of the American Institute of Baking (AIB) is to protect the safety of the food supply chain. AIB has created the quality system evaluation (QSE) quality management system with food safety is the main objective of certification (Stevenson, 2004).

For many firms, QMS and ISO certification provides the structure to improve operational efficiency, meet customer requirements. ISO certification also facilitates business transaction and guides management in operational decisions (Simmons and White, 1999; Van der Spiegel et al., 2005). Organizations may also adopt QMS to standardize operations, reduce product defects, and increase operational efficiency (Jones et al., 1997). QMS adoption has become the predominant means of addressing both competitive and customer requirements (Chang and Lo, 2005).

In the agricultural sector, previous QMS impact assessments generally have included the entire food supply chain (Caswell et al., 1998; Steenkamp, 1999; Capmany et al., 2000; Manning et al., 2006). These organizations have goals similar goals to those of non-agricultural businesses looking to QMS to improve internal operational and meet customer demands (Mumma et al., 2002; Rubio and Arias, 2005).

Measuring the impact of QMS requires data that not all companies are willing to share. This is reflected in the published research utilizing organizational data (Rubio and Arias, 2005). Results from the food supply chain perspective vary depending upon the product and process type, but most focus on microbial food safety (Zaibet and Bredahl, 1997; Schroder and McEachern, 2002; Fouayzi et al., 2006; Da Cruz et al., 2006). Food manufacturing studies have been the most predominant areas of research where processing measurements have been used to assess QMS implementation (Hooker and Caswell, 1999; Van der Spiegel et al., 2005).

There have been limited studies of the food supply chain post-harvest and before processing (Capmany et al., 2000; Mumma et al., 2000; Sullivan and Hurburgh, 2002; Hurburgh, 2003; Van der Spiegel et al., 2005). Because of the low margin of commodity products, when evaluating a QMS, company data remain the most valued performance metric in determining effectiveness. Although organizations within the agricultural and food supply chain have historically been reluctant to share internal data, context-specific operational data and methodology are needed to facilitate continuous improvement in industry processes. In-depth research outlining operational details of QMS usage is needed to continue to fill gaps in specific industry sectors, specifically in the area of post-harvest management of bulk commodity grains (Mumma et al., 2000).

Agricultural Cooperatives

The setting of this study was an agricultural grain handling cooperative. Cooperatives are customer-owned organizations that receive, store, and market grain products for producers and operate in the food and foodstuff supply chain (Williamson, 1998). The cooperative studied as part of this case study is the largest customer-owned cooperative in Iowa with more than 450 employees serving over 5500 members and covering a trade area greater than 3 million acres (4600 square miles).

Preparation for an expanded external market was the initial reason for adoption of the QMS at the case study cooperative. After the initial implementation, internal benefits from previous study were compiled and are shown in table 1. However, most benefits were measured through qualitative means. This study measured the indicators necessary to evaluate benefits of QMS quantitatively.

Table 1. Benefits of quality management in grain elevator operations.

Benefit	Measurement	Reference
Cost effectiveness	Improved operational efficiency	Hurburgh and Lawrence, 2003 Hurburgh, 2004
Process documentation	Defined job responsibility for employees	Hurburgh, 2003
Process documentation	Job descriptions and work instructions documented	Hurburgh, 2003
Employee development	Training criteria and job evaluation metrics established	Hurburgh and Sullivan, 2004
Employee development	Assignments and decision-making hierarchy clarified	Hurburgh, 2003
Statistical process control	Statistical analysis targets identified for quality control purposes	Hurburgh and Sullivan, 2004 Thakur and Hurburgh, 2009
Statistical process control	Methods developed for problem solving and corrective action	Hurburgh, 2003 Stevenson, 2004 Mosher et al., 2013
Statistical process control	Improved inventory management and blending procedures	Hurburgh, 2004 Laux, 2007 Thakur and Hurburgh, 2009
Regulatory compliance	Compliance with FDA Bioterrorism regulations	Hurburgh and Sullivan, 2004 Laux and Hurburgh, 2010
Regulatory compliance	Higher precision of grain traceability	Hurburgh and Sullivan, 2004 Laux and Hurburgh, 2010
Regulatory compliance	Enhanced correlation between occupational safety and quality management	Mosher et al., 2012

USE OF CASE STUDY METHOD

The characteristics of depth and detail needed for data analysis and valid conclusions may be derived from case study research (Rubio and Arias, 2005). Case study has many definitions, but most involve an in-depth study of a phenomenon within its real-life context (VanWynsberghe and Khan, 2007). Case studies may focus on the application of a specific variable or variables within a larger system, uncovering “layers of understanding” (Creswell, 2002). These layers in turn provide the parameters for the system, and the researcher focuses on a process or activity which operates within the larger system (VanWynsberghe and Khan, 2007).

Before data collection began, company benchmarks were created for the purpose of measuring the effectiveness of the QMS and its impact on operations. A subsequent study utilized the metrics identified previously to identify gaps between actual performance and targets for continuous improvement (Hurburgh and Sullivan, 2004). Using quality measures of internal performance and product performance data, this case study was conducted to determine if the organization realized any benefits from QMS implementation.

In addition to the case study methodology, this study utilized a business process management (BPM) model to quantify specific organizational benefits of QMS adoption. BPM, based on many of the same strategies as the case study approach, is structured around a small number of business processes or work flows, which link activities and employees in a functional enterprise (Strnadl, 2006). Utilizing BPM, there is recognition that organizational processes are developed for varying purposes to meet different needs. BPM provided a structured method for organizing, classifying and improving business processes within the grain elevator (Trkman, 2010). Furthermore, as noted by Trkman (2010), BPM is often case-specific. Little research on the use of BPM in grain handling has been completed, and because many processes of BPM aligned very well with the goals of quality management. (Utilizing BPM allowed this study to prioritize the processes, according to the research objectives, with regard to organizational goals of the QMS. BPM also provided the framework for identifying and measuring process indicators. The creation and refinement of these process indicators are discussed in greater detail in Laux (2007and will be the subject of a future manuscript.

The purpose of the project was to evaluate the effectiveness of the QMS in terms of grading accuracy and precision and value addition to discounted grain. Data were collected over a four-year period from six grain elevator locations. A portion of the grain elevators had adopted a formal quality management system based upon one of two systems: ISO 9001: 2000 requirements or the Quality System Evaluation (QSE) created by the American Institute of Baking (AIB, 2011). Accordingly, data were collected to answer the following research questions:

1. Is accuracy of grade grading in the areas of foreign material, damage, test weight, and moisture higher in locations using a formal quality management system (QMS) than in those locations not using QMS?
2. Is the precision of grade grading in the areas of foreign material, damage, test weight, and moisture higher in locations using a formal quality management system (QMS) than in those locations not using QMS?
3. Is the value of discounted grain blending recaptured in locations using a formal quality management system (QMS) than in locations not using QMS?

MEASUREMENT OF QUALITY INDICATORS

The management of grain quality encompasses several processes and is crucial to business performance. Grain elevators must receive, aggregate, store, and ship grain at a quality level that benefits the elevator and meets customer specifications (Barton, 1989). One critical aspect of this process is inventory management, which begins with the inspection of incoming grain. In-bound grain is inspected, blended, and stored according to quality grades set by the Grain Inspection, Packers, and Stockyards Administration (GIPSA), an agency of the United States Department of Agriculture (USDA).

Additionally, grain is a biological product, subject to deterioration. Low quality grain represents a risk to buyers and end users, in part because it decomposes at a higher rate than grain at a higher quality grade (Bern et al., 2008). Even given the importance of quality grades in storage decisions, grain quality measurements are difficult to standardize since some grading measurements are arbitrarily defined (Hurburgh, 2002). Fundamental dimensions of measurements in the United States are based on reference standards of the National Institute of Standards and Technology (NIST) for weight, volume, and length. However, there is no “absolute” measure of grain grades and official grades retain subjectivity resulting in measurement error (Hurburgh, 2002). The consistency of grading (precision) and closeness to the true value (accuracy, as defined by an official inspector) are important measurement characteristics in grain grading (Hurburgh 2002). The following characteristics are measured on each grain sample.

1. Test weight – Weight of measured volume of grain in grams per quart cup and struck off according to procedures outlined by the Federal Grain Inspection Service (FGIS); measurements were converted to kilograms per hectoliter (kg/hL) for this manuscript (FGIS, 2013)
2. Moisture content – The fraction (percent) of water on a total weight basis in grain sample measured by a calibrated Montomco© moisture meter calibrated by GIPSA (USDA, 2009).
3. Damage – The fraction (percent) of kernels with mold, or insect, disease, heat, or otherwise materially damaged by a visually sorted work sample (USDA, 2009).
4. Broken corn and foreign material – The fraction (percent) of all matter that passes readily through a 0.476 cm (12/64 in.) round-hole sieve and all matter other than corn that remains in the sieved sample after sieving according to procedures prescribed by the FGIS (FGIS, 2013)

All measurement has at least some variation introduced by operators. Damage has the most likelihood for variance, followed by foreign material, test weight, and finally moisture with very little operator error (USDA, 2009). Measurement of damaged grain and foreign material is most subjective, so greater variation was expected in these two processes. The grading process is based upon comparison of grain against two-dimensional visual aids for damage, introducing error. Sampling may also contribute to error, with wide and potentially unequal variance noted in the gaps between the in-house inspector and the official inspection (USDA, 2009). Errors in inspection and grading by in-house employees represent lost money or potential profit to an elevator. An effective quality management system should enable the elevator to use the errors as a way to add profit rather than a source of lost revenue (Hurburgh, 2003; 2004).

Once quality traits are measured, prudent management of grain through storage and shipping is an important inventory management strategy (Reed, 2006). If the grain is of low quality, there are risks for buyers in the receipt of lower quality grain. Furthermore, grain is a biological product, subject to deterioration, which in turn impacts its usability and marketability (Bern et al., 2008). Improving the measurement of grain quality through a quality management system allows a company to harness grain quality characteristics to better meet customer specifications (Sullivan and Hurburgh, 2002).

One method of enhancing customer service and managing grain quality is by the process of blending. Grain is inspected, dumped, and stored according to the quality grade. It is often commingled with other grain for blending at a uniform quality level at rail load out. In addition, at customer delivery, grain is often blended to produce a consistent level of grain quality, matching the customer specification. The ability to create a higher-grade grain lot from grain at lower quality levels enables the grain elevator to generate revenue in handling and storage operations. Through this process, an elevator operation may receive grain at a lower quality. The elevator then buys the grain at a discount from the producer and blends it with higher quality grain to create a shipping unit of material at a new, different quality level for the next customer in the supply chain (Hennessy and Wahl, 1997).

Additionally, grain defects impact the ability to manage grain storage and preservation processes so an effective blending strategy to reduce discounted grain stocks while maximizing the value of shipped grain is very important (Bern et al., 2008). The ability to create a higher-grade quality grain from varying quality grades of grain is a primary source of revenue in elevator operations (Bern et al., 2008). Thus, a key process indicator for inventory management is improving the grain quality measurement would allow the elevator to better meet product specifications (effectiveness) by blending various quality grades (Sullivan and Hurburgh, 2002).

Improvements in blending procedures also allow for an enhanced inventory management through more aggressive removal of defective and low quality grain during blending at shipping (by train or truck load-out). The accuracy and precision of grain grades is directly related to the effectiveness of the blending procedures. The more accurate and precise the grain grading process, the better the information used by management to formulate specific blends. This allows the grain elevator to blend away lower quality grain grades in higher amounts when shipping. Given that the grain elevator charges producers to receive low quality grain, when this grain can be blended with higher value product at shipping, the result is a higher profit margin by the end of the grain handling process.

To measure the accuracy in grade grading, as posed in the first research question, the amount of variance between the official inspection and the in-house inspector was recorded. Grade performance is a critical tool in management and storage decisions for grain (USDA, 2009). To measure the value addition captured by enhanced blending formulations (research question 3), the mean value of blended grain shipped by train was recorded and the percentage of mean value added to each train car was calculated. Results of these measurements are presented in the next section.

RESULTS

GRADING ACCURACY AND PRECISION

To measure QMS effectiveness in managing product grade quality, the difference between official and employee grades on single corn samples were calculated for the three primary grading factors of test weight, total damage, and broken corn foreign material (BCFM). Moisture content was also compared because of its importance as a quality factor in U.S. corn (Bern et al., 2003; Reed, 2006). The following equation was used to measure these differences:

$$\left| \text{FC Grade Factor} - \text{Official Grade Factor} \right| = \text{Absolute Mean Difference} \quad (1)$$

The absolute mean difference measured the accuracy of the grading process and the standard deviation of the mean difference values measured the precision of the grading, providing data for the first two research questions. Since there is no "true" value in cereal grain quality grades, the accuracy and precision of repeated measurements serves as the de facto criterion for the effectiveness of the grading process in managing the quality of grain. In measuring the absolute mean difference, samples were taken from out-bound rail cars at all QMS locations before and after their external quality certification. Sample data were also taken from selected non-certified locations.

The employees used the same procedure to grade samples at both the certified and non-certified locations. Each sample was inspected and graded by an elevator employee and a GIPSA inspector. Sample data were recorded for approximately 3 years, although missing data resulted in a different number of samples for each grade factor. The total data set with results from the quality grading process represents approximately 56 million bushels of corn. The data are presented as mean values for test weight, moisture content, total damage, and foreign material. Differences in means were tested using paired t-tests.

Table 2. Absolute differences between in-house and federal inspectors at QMS and non-QMS locations.

	Grade Factor							
	Test Weight		Moisture Content		Damage		Broken Kernels Foreign Material	
	n	Kg/hL (lb/bu)[a]	n	% pts.	n	% pts.	n	% pts.
Absolute mean difference								
Before ISO certification	1597	0.65_a (0.52)	1749	0.19_a	1637	8.68_a	367	0.85_a
After ISO certification	279	0.76_b (0.61)	279	0.21_a	110	1.77_b	94	0.53_b
Before QSE certification	2954	0.75_b (0.60)	2821	0.25_a	1197	2.71_a	272	0.76_a
After QSE certification	218	0.81_b (0.65)	218	0.25_a	79	1.44_b	27	0.49_a
No QMS certification	9299	0.70_a (0.56)	9299	0.22_a	2467	2.88_c	2211	0.61
Standard deviation mean difference								
Before ISO certification	1597	0.63_a (0.50)	1749	0.28_a	1637	4.41_a	367	0.94_a
After ISO certification	279	0.69_a (0.55)	279	0.19_a	110	1.26_b	94	0.46_a
Before QSE certification	2924	0.60_a (0.48)	2821	0.36_a	79	2.89_a	272	0.89_a
After QSE certification	218	0.54_a (0.43)	218	0.19_a	1197	0.99_b	27	0.79_a
No QMS certification	9299	0.58_a (0.46)	9299	0.27	2467	2.88_c	2211	0.89_a

[a] a, b, c Different letters indicate statistical difference at $p \leq 0.05$ using paired t-tests.

As expected, differences were noted between locations before they were QMS-certified as compared with locations after they were QMS-certified, although not all of these differences were expected. Because moisture and test weight are measured data and use calibrated methodology and machines to measure, little variation between pre-QMS and post-QMS locations was expected. This outcome was expected for both ISO and QSE certified locations. However, this was not the conclusion for test weight measurements with ISO certification, which showed a significant difference between the locations after ISO certification and sites before ISO certification. A higher difference in the test weight measurement differences at locations with ISO certifications is not expected. However, the differences represent less than 1/10th of a pound of difference, so although a statistical difference is noted, the difference observed may not have practical significance. Standard deviations of the test weight measurements were not significantly different but were approximately the same values as the means, suggesting that the variation in the measurement was high as compared with the means.

No significant differences were noted between facilities before and after certification on moisture content. This was the case for both ISO and QSE certified facilities. This conclusion was true for both the means and the standard deviation values, although a relatively high standard deviation was noted with the moisture content readings. The findings of no difference were not unexpected, given that moisture content is normally measured with a calibrated moisture meter that involves little to no human error potential (Reed, 2006).

The largest differences were expected in the two areas of grading that are more dependent on human skill and subjective decision-making: percentage of damage and percentage of broken kernels and foreign material. Significant differences were noted across both mean and standard deviation values for damage, with lower differences noted in locations post-certification than in locations before certification. For both ISO and QSE facilities, differences were observed between locations pre-certification and post-certification. Significant differences were also noted between facilities that were ISO and QSE certified and locations that were never certified.

Across all four grading areas, no observable pattern in the differences between in-house inspectors and official inspectors emerged. In some cases, the in-house inspectors graded higher than the inspectors, but in others, the official inspectors gave a higher grade. In all areas except for damage, where statistical differences were noted between graders, the differences were mostly statistical differences with little practical significance.

Damage had the greatest differences between the in-house and official inspectors. As was true in the other three grading areas, no observable pattern was evident. In some cases, the official inspectors graded damage much higher than did the in-house inspectors, but in others in-house inspectors noted more damage than official inspectors. However, when the difference between the in-house and official was large (greater than 10 percentage points), the official inspectors nearly always graded corn at higher levels of damage. The reason for this is unknown, but the lack of alignment illustrates one of the major challenges in grading commodity grain. Damage grades depend heavily on the sample drawn and the evaluation is extremely subjective. For this reason, a standardized procedure for in-house inspectors is important. Quality management systems can provide the standardization needed for more effective employee training (Trkman, 2010).

In the area of broken kernels and foreign material, only the ISO locations showed a significant difference between pre-certification and post-certification with mean and standard deviation readings. Locations observed a lower variation between the official and in-house grades post ISO certification than was noted pre-certification. Locations with QSE certification showed no significant difference before and after certification. No significant difference was noted between ISO certified locations and those facilities that had never been certified. The same finding was observed between QSE certified locations and facilities without any certification for grading on broken kernels and foreign material.

Blending Improvements

The second indicator of QMS effectiveness measured for this case study examined how well quality data could be managed and strategically used to add value to low-quality grain. The data on blending effectiveness provided information to answer research question 3 addressing adding value to discounted grain through improved blending procedures. An important component of this measure was the number of discounted grain bushels which were loaded on a train without financial penalty. The higher the number of discounted bushels loaded, the more positive the blending ability of the grain handling organization, and more importantly, the more effectively quality management was being used to add value to in-house stored grain. To calculate the value of the train when the lower cost grain was blended with higher quality grain for a homogenous, high quality shipment, a two-step calculation was used. The first equation measured the percentage of discount grain (that grain graded as 3, 4, 5, or sample grade):

$$\frac{\text{Discount bushels loaded}}{\text{Total inventory discount bushels}} \times 100 = \text{Percent discount bushels loaded} \tag{2}$$

Ideally, the grain elevator should remove its poor quality grain and blend it off as soon as possible to maximize profit potential (Hennessey and Wahl, 1997). In the equation above, discount bushels loaded were defined by measuring the discounted grain inventory in the storage bins in bushels. Once the train was loaded, another measurement was taken of the number of bushels remaining in the storage bins. The difference reflects the amount of discount grain removed. Next, the percentage of the value of the train loaded was compared to the total inventory of discounted bushels that could have potentially been loaded. To measure the effectiveness of management for discounted bushels, the percentage of discount bushels loaded on each train was compared between certified and non-certified locations. The results from this comparison are shown in table 3.

To calculate the value of the discounted grain that is loaded on the train, the discounted grain is assigned a value based on current market conditions and existing grain policies outlining discounts taken on grain that is evaluated with a grade of 3, 4, 5, or sample grade. Using a formula for blending that is proprietary to the grain elevator, the specific blend of discounted and high-quality grains was determined and a value was created for each load of grain. The following equation is then used to calculate the value of the grain load containing the blend of high quality grain and discounted grain on a per train basis.

$$\frac{\text{Discount grain value loaded on each train}}{\text{Number of railcars per train}} = \text{Discount blend value per railcar} \tag{3}$$

Data were collected from a sample of 141 trains over 4 years, each with an average of 110 cars per train. Each car held approximately 3500 bushels of grain. Corn was used as the test grain in this case study, as corn represents 65% to 70% of this elevator's grain volume. To calculate whether a statistical difference existed between QMS locations and non-QMS locations in the value added for each train, the value of discounted grain in number of bushels loaded was calculated. Grain policies from for total damage, heat damage, and foreign material were used from April 2014, with a base price of $4.28 per bushel and a $0.14 discount per bushel for samples graded as 4, 5, or sample grade. Sample grade characterized over 97% of the grain samples taken as shown in figure 1. It is these grain lots along with lots graded as 4 and 5 that are blended with higher quality grain to form a higher quality final grain load. This revenue can make up a significant portion of revenue when managing low quality grain (Hellevang, 1995).

To find the mean value per train and per train car for QMS-certified sites as compared with non-certified sites, the mean value of all of the trains and all of the corresponding train cars were calculated, assuming 110 cars per train. Differences in mean values were tested using a paired t-test. These values are shown in table 3.

Elevator locations with a certified-QMS program in place saw a significantly higher mean value per train and mean value per train car, but also saw a much larger standard deviation per train. This suggests that QMS-certified locations were able to capture additional value at a higher level than non-certified locations. The value was not captured consistently because as the mean values of the grain increased for trains from QMS locations, the standard deviation followed as well. For example, in quality process control, eliminating special cause variation would be a goal for statistical process control (Juran and Godfrey, 2000). However, in this case, where the special cause variation is the number of discounted bushels loaded, the increased amount of discounted bushels loaded in each train car would increase the value added. In addition, if there was a train with a high level of discounted bushels, there would be no effort to reduce that dollar volume but capture it as a management decision. Thus, mean and standard deviation values both increased in QMS locations because the value added to each train car was higher.

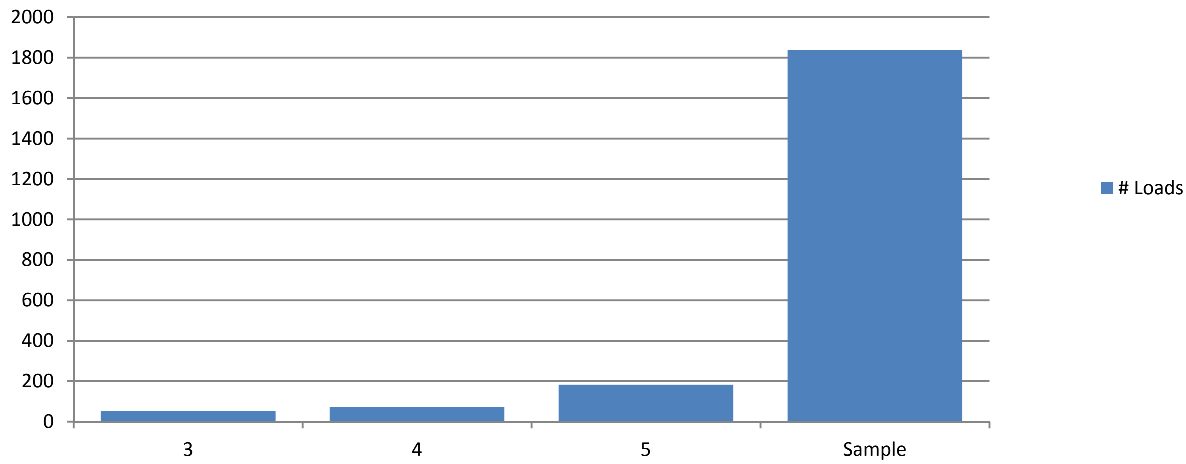

Figure 1. Grades of discounted grain loads (N= 2147).

Table 3. Blended grain summaries from QMS and non-QMS locations.

Quality System	No. of Trains	Mean Value per Train[a]	Mean Value per Train Car	Standard Deviation per Train	Percentage Discount Bushels Loaded (%)	Percentage Value Captured (%)
ISO and QSE certified grain elevator locations	81	$31,916[a]	$290.15[a]	$671.80[a]	25.79%	12.35
Non-certified grain elevator locations	60	$12,268[b]	$111.53[b]	$148.31[b]	18.62%	7.26

[a] a,b Different letters indicate statistical difference at $p \leq 0.05$ using a paired t-test.

CONCLUSION

The purpose of the project was to evaluate the effectiveness of the QMS in terms of grading accuracy and precision and value addition to discounted grain. Data were analyzed to answer three research questions. The first question asked about the influence on the accuracy as measured by the mean difference between the in-house grader and the official grade on four quality grading traits. The greatest improvement in accuracy was seen in the quality trait of damage. Significant statistical differences were also noted in ISO certified facilities in test weight and broken kernel foreign material (BCFM) accuracy. Through quality management systems, tasks definition can be enhanced, which in turn can improve quality control and the ability of the grain elevator to manage their inventory more strategically. Improved knowledge of quality traits also provides data to make decisions on marketing, blending, and storage options. In this case, enhanced grading accuracy was noted, but not consistently. ISO-certified facilities saw more improvements than did QSE-certified locations.

An unexpected finding was a statistical difference in test weight between pre-ISO-certified facilities and post-ISO-certified facilities. Test weight has a specified and objective measurement protocol (Reed, 2006), so significant differences are both unexpected and undesirable. Although the origin of these differences cannot be determined conclusively, they can be attributed to several factors, including: scale accuracy, measurement error, and workers taking unauthorized liberties in their measurement procedures.

The second research question addressed whether quality management systems in ISO and QSE could improve the precision between in-house and official graders. Precision in this case was measured by the mean values of the standard deviation of in-house and official grades. Significant differences were noted in post-ISO-certified facilities in damage and BCFM, and in post-QSE-certified in damage. These data suggest an improvement in grading precision with damage and BCFM, both subjective assessments. However, in several cases, the standard deviation values were high in relation to the mean values, suggesting a lower level of precision than is desirable.

The final research question addressed the ability of ISO and QSE-based quality management systems to add value to discounted grain with more strategic blending formulations. Specific blending formulations are proprietary information, but the outcome of the blending as measured by the added train value, portion of discounted bushels loaded, and the percentage of value addition captured reflect the effectiveness of blending activities. ISO and QSE-certified facilities saw significantly higher value per train, higher percentage of discount bushels loaded, and higher percentage of value captured. These suggest that strategic blending that is guided by an ISO or QSE-based QMS has the potential to add significant value to commodity grain purchased by the grain elevator at a discount. A significantly lower significant difference was noted for certified facilities, suggesting a greater level of precision in blending as well.

This case study has demonstrated that continuous improvement in grading and blending is possible with ISO and QSE-based QMS can impact company performance positively. Furthermore, although bulk commodity grain quality can be difficult to manage, QMS adds another tool for continuous improvement in a low-margin, competitive business environment.

As with all studies, there are limitations to the findings shared here. These data were collected over four years from one agricultural cooperative. The standard operating procedures of this cooperative may not reflect industry practice in all areas. Additionally, the data used were gathered by employees for the most part, potentially introducing measurement and recording errors. They may be minor in nature or more substantial – this is one issue in using company data, but it is one the authors were willing to tolerate, given the benefits of using actual company data. Finally, the QMS procedures used by this agricultural cooperative were created and developed to specifically meet their business needs. Needs of customers, workers, and other important stakeholders are primary considerations in many QMS programs and this one was no different. A generic model of quality management may not be as effective in other environments, even those in bulk grain handling.

Even with these limitations, the data provide evidence that a commodity business can enhance internal procedures such as grading and add value to shipped grain products with better management and usage of quality-based data. The development, adoption and receipt of QMS are not easy processes, but when the outcome is an improvement in business excellence and continuous improvement, most would consider the results worth it.

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