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04

Applying DMAIC Methodology to Reduce Egg Breakage Rates in Small-Scale Production Enterprise in Mandalay Region

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Abstract

This study employed the DMAIC methodology (Define, Measure, Analyze, Improve, Control) to investigate and minimize Unusable egg breakage (Completely broken eggs) at Golden Yolk farm. Data was collected using a triangulated approach that included direct observations of egg-handling processes, interviews with experienced farm personnel, and a review of historical breakage records in order to ensure reliability. Standardized checklists were also used, and initial analysis revealed a total defect rate of 0.74%, with Unusable breakage being the highest contributor at 0.47% among all types of defects. Qualitative tools like Pareto charts, FMEA, and Fishbone diagrams identified the main culprits of inadequate handling techniques and the absence of appropriate equipment. Subsequent interventions focused on implementing farm personnel training, standardized handling procedures, and introducing relevant equipment, significantly reducing Unusable egg breakage from 0.47% to 0.39%. This approach demonstrates the effectiveness of the DMAIC methodology for addressing Unusable egg breakage in the egg farm. These findings offer valuable insights for improving farm operations, ensuring consistent, high-quality egg production, and minimizing associated losses.

Keywords: DMAIC, FMEA, SIPOC, Pareto analysis, Fishbone diagram, Unusable egg breakage

Introduction

The egg is the most popular food worldwide because of its nutritious value**.** It provides crucial micronutrients in the correct ratio of essential amino acids, vitamins, and minerals required to maintain good health**.** The egg industry is currently facing a significant issue of egg breakage**.** This problem not only harms the egg but is also associated with environmental threats at large**.** This issue not only represents wasted food but also raises environmental concerns**.** By minimizing breakage, families gain a cost**-**effective and sustainable protein source, while farmers potentially save money over time, which we hope would translate into lower grocery bills for everyone down the line**.** Beyond the prevention of broken eggs lies the more profound concern of good food for all, our communities, and neighborhood**-**scale sustainability**.**

Dr**.** Michael, a veterinarian committed to animal welfare, established The Golden Yolk Egg Farm as a small farm in Mandalay, Myanmar in 2008**.** The farm comprises 3 Acres **(**7 Rai**)** and 4 houses with the same operating system**.** There are about 100,000 hens on this farm, with each house containing around 25,000 hens**.** The farm aimed to create top eggs while caring for bird welfare first**.** Battery cage systems frequently use automated technology to enhance the efficiency and well**-**being of the birds**.** Automated feeders and waterers provide consistent access to resources, while climate control systems, such as large fans in each house, automatically regulate temperature, humidity, and ventilation to optimize egg production and bird health**.** However, the farm does not invest in technology for collecting eggs**.** Thus, it has 4 farm managers to oversee 40 workers daily. Yet despite their increased success at becoming an excellent farm, there**'**s a significant problem with eggs breaking on the farm that is causing them distress and losing customers due to dissatisfaction**.** The core issue at the egg farm is that of egg breakages, which significantly impact the entire supply chain**.** This resulting problem leads to lost money and unhappy customers**.** From January to March 2023, the total egg production across the four houses was 6,968,552 eggs**.** During that time, according to the data, there were 51,684 eggs with defects, including unusable broken, large cracks, calcium deposits, wrinkles, pinholes, and weak shells**.** These defects represented about 0**.**74 percent of total eggs produced, highlighting the immediate need for addressing and reducing egg breakage in the operations**.**

Research Objectives

1. To identify the key factors contributing to broken eggs in the egg production industry and develop improvement strategies using the DMAIC method to address the root causes of broken eggs**.**
2. To evaluate the effectiveness of methods and strategies in reducing the highest contribution of defects **(**Unusable egg breakage**)** by less than 0**.**47**%.**
3. To develop a monitoring system to sustain improvements and prevent future occurrences of broken eggs**.**

Literature Review

Condé et al. (2023) stated that the DMAIC technique uses the study to investigate the causes of problems and suggest mitigation strategies. The researchers guided the project execution using a structured methodology known as Define-Measure-Analyze-Improve-Control (DMAIC).

According to Hakimi et al. (2018), the Define phase is the most crucial step in creating a business case for the issue. It forms the foundation for securing decision-makers support by highlighting the potential cost reduction associated with mitigating issues impacting profit. Tools like Pareto charts mentioned by Beheshti et al. (2018) help pinpoint the highest contributing factors to the problem, allowing focused problem-solving efforts. According to Samuel et al. (2019), Pareto analysis is a valuable technique for prioritizing improvement efforts when faced with numerous competing potential causes or courses of action. Additionally, Assis de Souza et al. (2022) used SIPOC (Supplier-Input-Process-Output-Customer) charts to map existing activities and key process elements visually.

Next comes the Measure Phase, Kumar et al. (2021) emphasized that it involves collecting and measuring the data using a reliable measurement system that assesses the process's status. Process maps, as advocated by Antonacci et al. (2021), can be instrumental in this phase. They enable the identification of areas for improvement, facilitate the streamlining of existing systems, and contribute to the creation of targeted measurements.

The Analyze phase delves deeper into the causes of egg breakage. According to Mittal et al. (2023), the Analyze Phase utilizes Pareto charts and fishbone diagrams to identify major defects and their root causes for quality improvement initiatives. According to Coccia (2015), fishbone diagrams (Ishikawa diagrams or cause-and-effect diagrams) display various causes of a specific event or phenomenon. For a more comprehensive analysis, Ionescu et al. (2022) described that FMEA (Failure Modes and Effects Analysis) systematically examines potential failures and their effects on a system, using a Risk Priority Number (RPN) to prioritize corrective actions.

Building on the Analysis Phase diagnosis, Milki (2022) emphasizes the Improve phase of DMAIC, which focuses on developing corrective actions to address the root causes identified earlier. Ali (2021) stated that the Control Phase safeguards sustained improvements by monitoring implemented solutions, ensuring adherence to revised processes, and potentially incorporating customer feedback through surveys to verify continued effectiveness.

Methodology

The researchers used the DMAIC method to study egg breakage in the Golden Yolk Egg Farm. With the use of the DMAIC method, researchers confidently solved the issue of egg breakage and successfully identified and addressed the underlying causes. The result was a remarkable reduction in broken eggs throughout the production process.

Collection Methods

1. Researchers directly observed the egg production process in all four houses, focusing on areas with suspected high breakage rates. Since the four houses utilize the same operating system, insights gained from one house could be readily applied to the others. Semi-structured interviews were conducted with farm personnel, including managers and workers, to gather their experiences with egg breakage during various production stages.
2. A broken egg checklist was developed to ensure consistent data collection across different areas and all four houses. This checklist would likely include factors such as rough handling practices, collisions with equipment, weak eggs entering the production line, improper tray stacking, and excessive vibration during transportation. By capturing data on 100% of observed defects, the researchers aimed to obtain a complete picture of breakage issues.

3. Brainstorming sessions were held to identify potential causes of egg breakage. These sessions involved farm owner, farm personnel and researchers. Their combined knowledge and experience from different areas of the production process were crucial in pinpointing potential causes.
4. Data collection included reviewing existing farm records. Specifically, researchers analyzed data sheets maintained by quality control inspectors at the end of the production line. This data provided valuable insights into the types and frequency of egg defects encountered during the final inspection. The DMAIC model was then implemented to structure the analysis and improvement efforts.

DMAIC:

The purpose was to establish the primary factors behind egg breakage and implement effective solutions to resolve this issue, as shown in Figure 1.

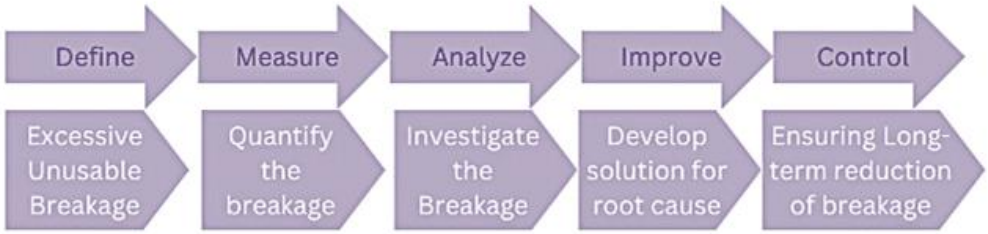

Figure 1 The stages of DMAIC (Source: Researcher, 2023)

Define Phase:

Researchers at the egg farm started by meeting with workers to discuss egg breakage issues. Subsequently, a comprehensive review of the entire egg production process was conducted. Following the Define phase of the Six Sigma DMAIC model, the project focused on identifying the Critical To Quality (CTQ) characteristic—in this case, minimizing Unusable broken eggs—as the farm posed a significant financial burden and impacted overall production efficiency.

As shown in Figure 2, the SIPOC analysis is a useful tool that can provide a foundation for deeper investigation**.**

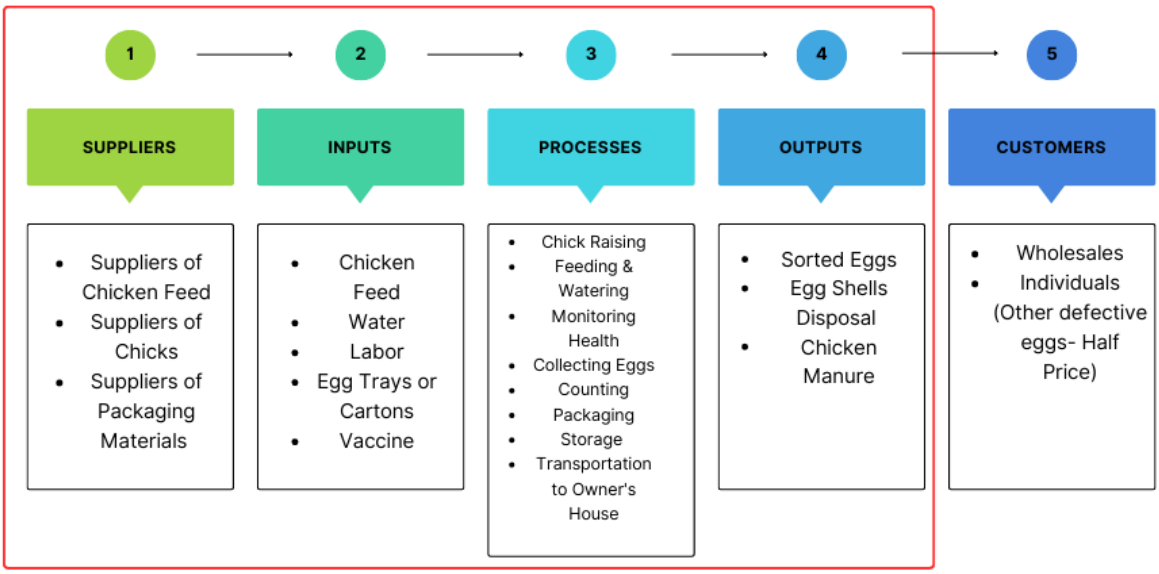

Figure 2 SIPOC of the Golden Yolk Egg Farm (Source: Researcher, 2023)

Examining each process step, from the quality of chicken feed supplied by vendors to loading the eggs onto trucks for transport, potential breakage points can be identified **(**represented by the red box in Figure 2**)**, signifying that the farm is responsible for any breakage from suppliers to outputs**.** By analyzing data on broken eggs collected at different stages of production, the farm can pinpoint areas most likely to break, allowing them to implement targeted improvements and ultimately minimize Unusable broken eggs**.**

The results of the farm data are presented in Table 1, highlighting the most frequently encountered types of defective eggs. The Pareto chart (Figure 3) underscores the significant impact of the Unusable Broken Eggs category, making it a central research focus. Unusable Broken Eggs are completely broken eggs that are unfit for consumption and sale. According to Table 2, The Unusable broken egg category, accounting for 0.47% (33,140 eggs) of the first quarter's 2023 production (6,968,552 eggs), is the primary focus of improvement efforts. While other defects such as Large Cracks, Calcium Deposits, Wrinkle, Pinhole and Weak shell allow for discounted sales, Unusable broken eggs represent a complete loss and require immediate attention. Importantly, focusing on solving the issue of Unusable Broken Eggs may also lead to a reduction in other types of defective eggs. Addressing the root causes of Unusable breakage has a positive ripple effect, ultimately improving the overall quality of the eggs produced.

Table 1 Comparing Frequencies of Defective Eggs **(**Q1, 2023**)**

Categories	Frequencies	Percentage (%)	Cum. Relative Frequencies (%)
Unusable Broken	33,140	64.12	64.12
Large Cracks	15,213	29.43	93.56
Calcium Deposits	2,216	4.29	97.84
Wrinkle	694	1.34	99.19
Pinhole	294	0.57	99.75
Weak shell	127	0.24	100
Total	**51,684**	**100**	

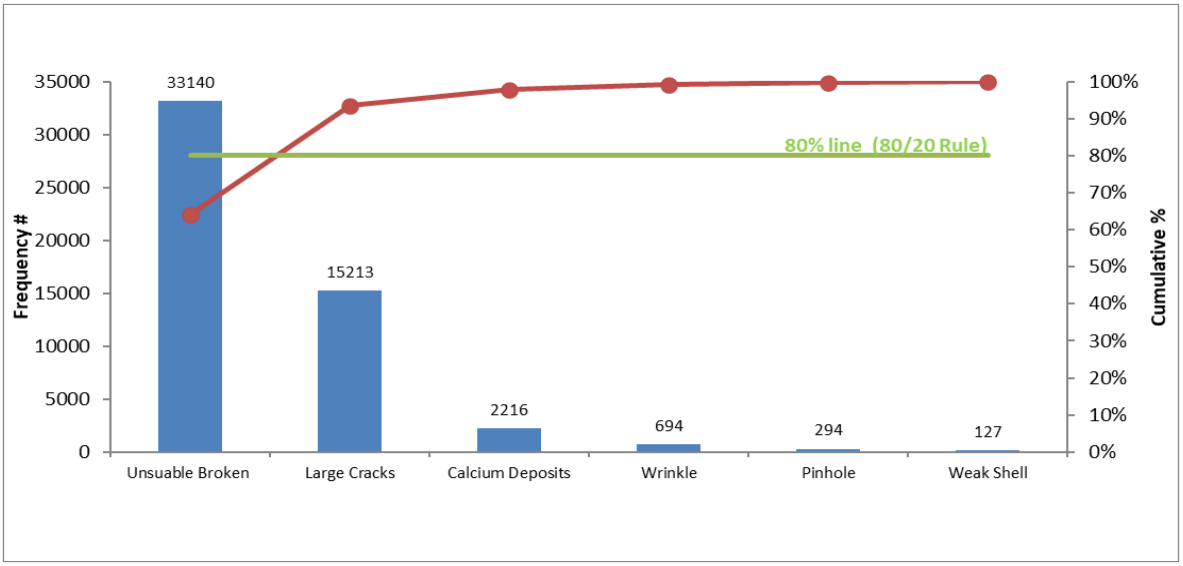

Figure 3 Pareto Chart of Total Egg Defects (Source: Researcher, 2023)

Table 2 Unusable Broken Eggs Frequency at Golden Yolk Farm **(**Q1, 2023**)**

Unusable Eggs		House A	House B	House C	House D	Total Broken	Total Production
Before	Jan	997	2,364	4,231	2,366	9,958	1,946,123
	Feb	1,953	921	5,177	2,400	11,724	2,445,293
	Mar	2,508	2,077	4,959	1,914	11,458	2,577,136
Total						**33,140 (0.47%)**	**6,968,552**

Measure Phase:

The researchers conducted interviews with the farm owner and collected information from various sources within four houses operating under the same farm. The farm uses its records, which include production, sales, inventory, chicken age, temperature, and egg counts tracked by monitoring systems in farm operations. The workers collecting eggs from the conveyor belt observed daily production in this study. The farm managers accurately recorded the daily egg production count using a standardized checklist to ensure consistent data collection and documentation. The researchers further enhance transparency through a detailed process map (Figure 4). This visual representation showcases the interconnectivity of the departments, highlighting the roles and responsibilities of each team member, from top-level management procuring resources to farm workers implementing quality control measures.

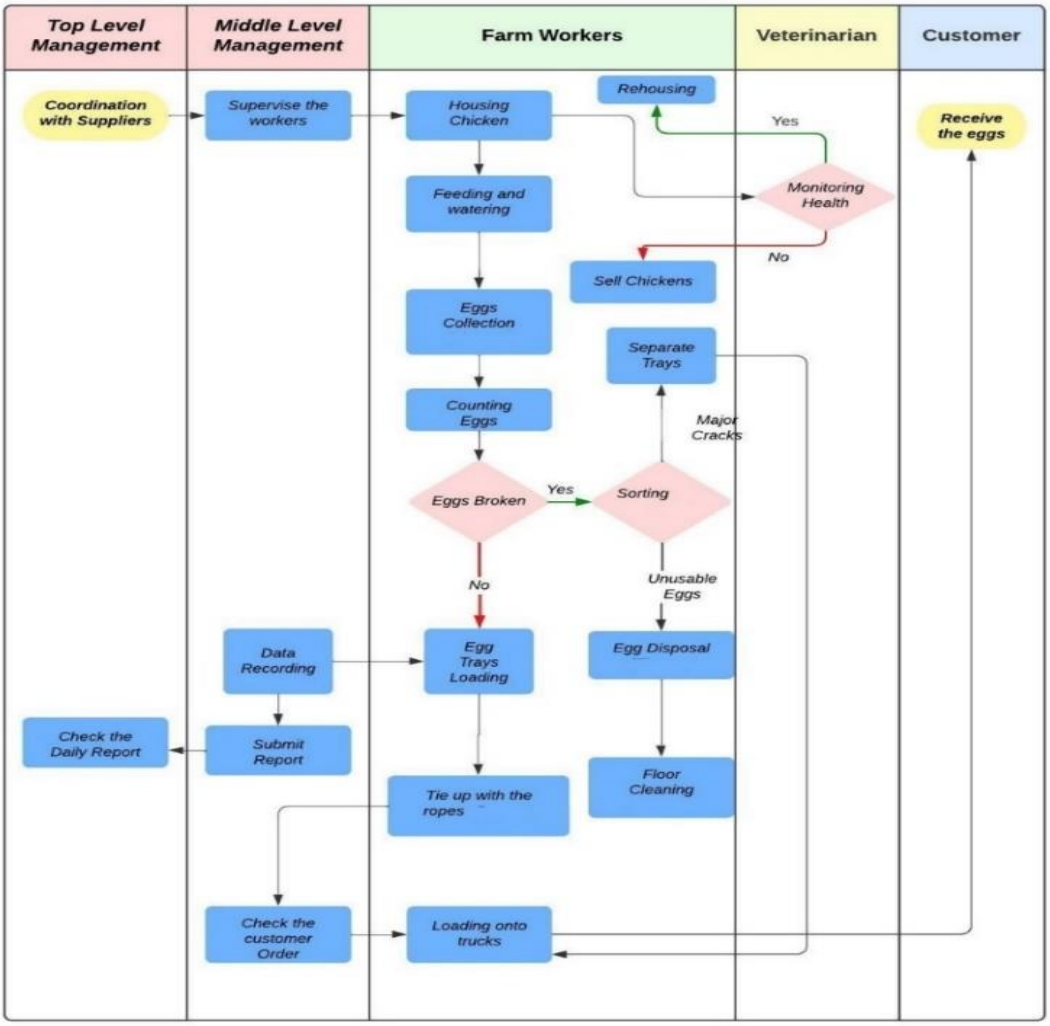

Figure 4 Detailed Process Map of the Golden Yolk Egg Farm (Source: Researcher, 2023)

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Analyze Phase:

The primary objective of the Analyze phase of the egg farm project was to establish the underlying reason for egg breakage. Different tools and techniques can be used to analyze this issue. A Fishbone diagram is one of the tools commonly used in this study. Figure 5 of the Fishbone Diagram reveals several crucial factors contributing to the farm's egg breakage issue. First, a brainstorming session was conducted with farm owners, managers, and workers. Their combined expertise across different aspects of the production process provided valuable insights into potential causes of breakage. Second, observations were made throughout the production line, focusing on areas with suspected high breakage rates and equipment operation. Finally, data from production records was reviewed to identify trends and patterns in breakage incidents.

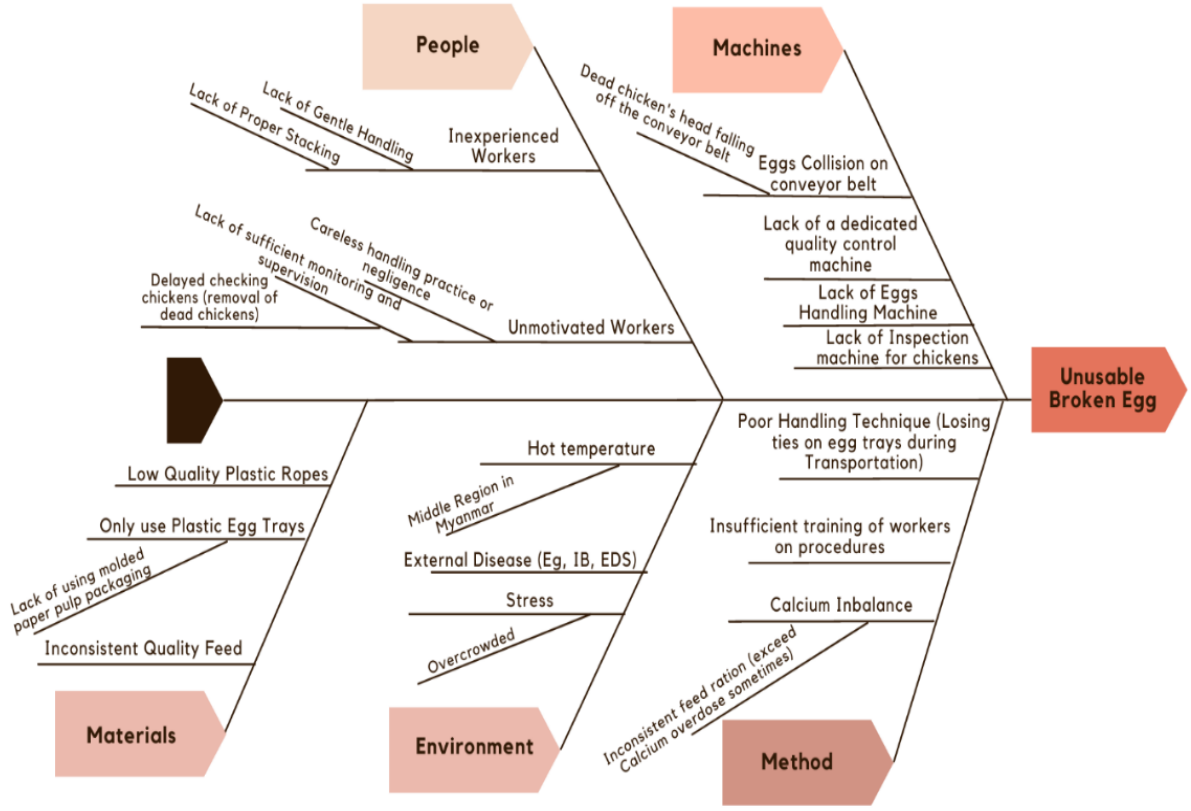

Figure 5 Fishbone Diagram of Golden Yolk Egg Farm (Source: Researcher, 2023)

As depicted in Figure 6, Unusable egg breakage involved machine-related issues, inadequate quality control equipment, environmental conditions, material choices, staff handling methods, and human factors. Information for the analysis was gathered from various sources, including production records and interviews with farm owners, managers, and workers.

Figure 6 Factors Contributing to Egg Breakage: Machinery and Worker Actions
(Source: Researcher, 2023)

The connection between FMEA and Fishbone analysis lies in their complementary roles. Fishbone analysis helps us find the root causes, allowing us to address egg breakage and prevent it from happening in the first place. According to Table 3, FMEA helps us identify what could go wrong and prioritize issues based on their potential impact. We calculate a Risk Priority Number (RPN) for each potential failure mode, considering the severity, occurrence, and detection scores. By focusing on failure modes with the highest RPN scores, we can prioritize tackling the issues that pose the greatest risk to egg quality and farm efficiency.

To get the score, each expert who has worked with more than 10 years of experience was provided with a standardized scoring sheet and FMEA training materials. They independently rated the severity, occurrence, and failure mode detection on a scale of 1 (low) to 10 (high). For FMEA, during the discussion, each expert explained their reasoning behind the scores they assigned for each factor (severity, occurrence, and detection). This rationale-sharing helps the group understand the perspectives and considerations that went into each rating. The ultimate goal of the discussion is to reach a consensus on the final scores for each factor. This means they strive to agree on a single score for each factor (severity, occurrence, and detection) after considering their diverse perspectives and rationales.

Table 3 FMEA (Failure Modes and Effects Analysis)

						Current Process Control			
Item/Function	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Cause	OCC	Prevention/ Detection	DET	RPN	Responsibility and Duration (From 1st of May)
Inexperienced Workers	Poor handling, Lack of Knowledge	Increase egg breakage, Reduced productivity	9	Insufficient training on procedures	9	Supervised	4	324	Farm Managers/ Farm Workers (Within two months)
Unmotivated Workers	Careless handling practices, Low responsibility	Higher chance of egg breakage by mishandling	9	Unfavorable working conditions, lack of recognition	8	Supervised	5	360	Farm Managers/ Farm Workers (Within a week)
Low-Quality Plastic Ropes	Breaking, Losing Tie, Weak Support	Potential Damage to eggs	7	Not using better packaging	7	Regular Quality Check	4	196	Farm Manager (Within two weeks)
Plastic Egg Trays	Fragile, Stacking Issues	Increased risk of egg breakage	6	Poor quality control during procurement	6	Regular Quality Check	4	144	Farm Manager (Within two weeks)
Inconsistent Quality Feed	Varying nutrients level	Weakened eggshells, Lower egg quality	7	Unreliable Suppliers	5	Strict Supplier Quality Control	3	105	Owner (Within three months)
Hot Temperature	High heat exposure	Soften shells, Lower egg quality	6	External temperature, Electric Shortage	7	Solar system	2	84	Owner/Farm Manager (Within three months)
External Disease (e.g., IB or EDS)	Spreading Disease in the flock	Increased hen mortality and reduced eggshell' quality	8	Improper disease preventive measures	5	Strict Biosecurity Protocols	3	120	Veterinarian/ Farm Workers (Within three months)
Stress	High-stress level hens	Reduced hen health and egg quality	6	Overcrowding and uncomfortable environment	4	Optimize Housing Conditions	3	72	Farm Workers (Within a week)
Egg Collision on Conveyor Belt	Eggs Colliding with each other	Increased risk of egg breakage	7	Hen's head fell off the conveyor belt	6	Regular Inspection	4	168	Inspector (Within a week)
Calcium Imbalance	Imbalanced levels in feed	Weakened eggshells and Increased breakage	7	Inconsistent Feed Formulation	4	Testing of Feed	2	56	Veterinarian (Within two months)

						Current Process Control			
Poor Handling Techniques	Improper handling methods of eggs	Increased Egg breakage rate	8	Lack of proper training and procedures	7	Supervised	4	224	Farm Manager/ Farm Workers **(**Within a week**)**
Lack of Inspection Machine for Hens	Absence of specialized machines for egg inspection	Unaware of dead or diseased hens	5	Lack of investment in inspection Machine	4	Considering investing in an inspection machine	6	120	Owner **(**Within five years**)**
Item/Function	Potential Failure Mode	Potential Effects of Failure	S E V	Potential Cause	O C C	Prevention/ Detection	D E T	R P N	Responsibility and Duration **(**From 1st of May**)**
Lack of Dedicated Quality Control Machine	Inadequate Quality Control Machine	Some unknown defect types **(**or**)** Undetected defects	5	Lack of investment in Quality Control Machine	3	Considering implementing a quality control machine	6	90	Owner **(**Within five years**)**
Lack of Eggs Handling Machines	Absence of specialized machines for Handling	Increased egg breakage, Inefficient handling, and sorting process	7	Not prioritizing investing in Handling Machine	8	Considering investing in handling machine	6	336	Owner **(**Within five years**)**

The highest RPN (Risk Priority Number) score was 360, and the lowest RPN score was 56. Inexperienced workers, unmotivated workers, lack of egg-handling machines, and poor handling techniques linked the failure modes with the highest RPN scores. Ensuring proper training for workers is crucial in preventing breakages. This emphasizes the need for additional training for those who lack the necessary skills. It's also essential to provide favorable working conditions and recognition to avoid demotivation among employees. This can have negative consequences that could affect the quality of work. Investing in egg-handling machines should be a priority to ensure efficient and effective egg handling. Proper handling techniques are essential to prevent issues arising from failure to follow correct protocols.

Improve Phase:

After using the Fishbone Diagram and FMEA, the researchers identified the factors that should be prioritized and searched for optimal solutions to resolve the egg-breaking problem at the farm. The primary focus of this study was to identify more efficient strategies to assist production teams in preventing egg breakage. The researchers explored innovative methods to decrease egg breakage, minimize losses, and enhance customer satisfaction. Additionally, the researchers examined ways to enhance the product and improve operational procedures, leading to improved overall performance of the egg farm.

Firstly, the owner and the managers organized weekly team meetings to promote collaboration, improve communication, and educate employees. These meetings provided an opportunity to share ideas, enhance skills, and stay updated with industry trends. A one-month on-the-job training program was implemented in May 2023. The training covered essential topics like farm policies, safety procedures, egg handling techniques, equipment operation and maintenance, and biosecurity measures. Through workshops and practical sessions, new workers learned to handle eggs gently, identify damaged eggs, pack them efficiently, and maintain proper storage conditions. This comprehensive training, led by a team of experts, including veterinarians, managers, technical trainers, and experienced workers, resulted in a demonstrably improved ability of the new hires to perform their tasks effectively. Phasouk et al. (2021) also stated that most farmers need more training skills and knowledge of raising chickens.

A standardized work instruction form was developed to promote consistency in task performance. This has resulted in a decrease in mistakes, improved operational excellence, and upheld quality standards. To enhance worker morale and productivity, a new schedule was implemented to ensure equal rest and revitalization opportunities for all employees. An incentive program was put in place that included bonuses and overtime pay that were dependent on performance. This serves as a motivation for employees to work in their respective roles. Worker evaluations were conducted individually to offer tailored feedback. This facilitated conversations about enhancing performance and pinpointing areas of strength and improvement. Suitable equipment, such as egg tray racks and rubber bands to tie the trays (instead of using plastic), was provided to ensure careful handling and transportation of eggs. This measure effectively reduced egg breakage and maintained hygiene standards. In order to maintain high standards and ensure smooth operation, the equipment, hens, and eggs were inspected three times daily. This allows workers to identify any sick hens, leading to improved early detection of issues and preventing dead chickens' heads from falling out and potentially causing egg collisions. (Figure 7)

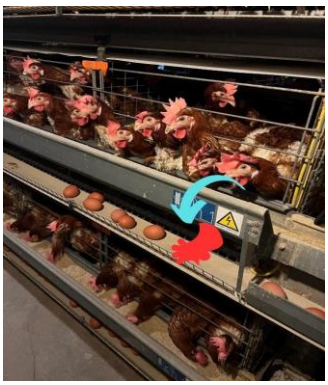

Figure 7 Illustration of a Potential Scenario of Egg Breakage
(Source: Researcher, 2023)

Control Phase:

In the Control Phase of the DMAIC methodology for egg farming, the focus is on maintaining and reinforcing improvements made in the earlier stages. The critical elements in this phase are as follows:

Standard Operating Procedures (SOP): Consistency and efficiency in farming activities such as egg gathering, handling, sanitization, and preservation can be achieved by implementing transparent and standardized operating procedures (SOPs). These SOPs guide best practices, safety protocols, and quality assurance.

Weekly Team Meetings: Regular meetings are held by the farm team to assess progress and address issues and strategies for ongoing enhancements. Key stakeholders, such as owners, farm managers, and relevant staff, collaborate to review performance metrics and pinpoint opportunities for improvement.

Visual Kanban: Process control can be enhanced by incorporating visual controls such as Kanban systems. By utilizing visual cues, such as colored tags or labels on egg trays, workers can understand what to do, reinforcing the importance of careful handling. By assigning different colors to different egg categories, workers can efficiently categorize and manage them.

Results

By implementing these strategic actions, the farm attempts to maximize its efficiency. It continuously monitored performance to achieve the desired outcomes so that the farm could ensure long-term success by effectively managing and controlling the processes throughout the DMAIC journey.

FMEA Action Result: The researchers focused on enhancing the factors with the highest RPN after conducting the FMEA analysis (Table 3). The highest RPN scores were inexperienced workers, unmotivated workers, lack of egg-handling machines, and inadequate handling techniques. Despite the high RPN score associated with the lack of egg-handling machines, immediate action is challenging due to time constraints, budget limitations, and market demands. Nonetheless, it was noted that factors with lower RPN scores, such as low-quality plastic ropes, plastic egg trays, and egg collision on conveyor belts, also showed interconnectivity with these improvements. As a result, by focusing on the top three priority concerns, additional related problems could be resolved effectively. The action plans that were created are presented in Table 4.

Table 4 FMEA Action Plan

Item/ Function	Previous RPN	Recommended Actions	Action Results				
			Action Taken	SEV	OCC	DET	RPN
Unmotivated Workers	360	Provide incentives or rewards and implement motivation Strategies	Announce Scheduled Break Times, Implement Employee Reward and Incentives Programs, Conduct employee Surveys	9	4	2	72
Lack of Eggs Handling Machines	336	-	-	-	-	-	-
Inexperienced Workers	324	Enhance Training Program to improve their skills	Provide Clear Work Instructions Form, Conduct on-the-job Training, Conduct Team Meetings for Knowledge Sharing	9	3	3	81
Poor Handling Techniques	224	Improve Training and proper handling methods	Provide Proper Equipment for Handling, Conduct Regular Quality Inspection	8	3	2	48
Low-Quality Plastic Ropes	196	Source Higher Quality Packaging (Rubber Band)	Provide Proper Equipment for Handling- Rubber bands	7	4	3	84
Plastic Egg Trays	144	Replace with more Egg Trays Racks	Provide Proper Equipment for Handling- Eggs Racks	6	3	2	36
Egg Collision on Conveyor Belt	168	Worker Accountability and Follow the schedule with stricter inspection	Conduct Regular Quality Inspection	7	2	2	28

Based on the researchers' recommendations, it is imperative to implement incentives, surveys, and break time for unmotivated workers to achieve a highly engaged workforce. It is crucial to prioritize improved training to reduce breakage incidents and provide better instructions and equipment to increase effectiveness. The absence of egg-handling machines poses a high-risk issue that requires immediate attention. Unfortunately, financial constraints have prevented investment in new equipment, but this must be overcome to ensure a safe and efficient workplace.

As shown in Table 5, the initial defect rate of 0.47% was successfully reduced at the egg farm following the implementation of significant approaches to address and resolve the loss of 33,140 eggs. After the performance was completed, a decrease in the defect rate of 0.39% was observed. The loss of 30,175 eggs accompanied this result. In the second quarter, the loss incurred decreased by 7,355,156 Ks (or) 91,939 baht. (Note: As the optimal time for the chickens to lay eggs arrived, there was an increase in egg production.) The goal set for the chicken farm was to achieve at most 0.40% broken eggs. Therefore, the farm is moving towards this goal because of the effective use of the newly developed techniques, which a significantly reduced defect rate has aided. To ensure the improvement's continuous lifetime, the farm must

maintain constant awareness by tracking performance, identifying potential issues, and taking the necessary actions.

Table 5 Before and After Implementation

Unusable Eggs		House A	House B	House C	House D	Total Broken	Total Production	Total Loss
Before	Jan	997	2,364	4,231	2,366	9,958	1,946,123	8,077,500 Ks (or) 100,973 Baht
	Feb	1,953	921	5,177	2,400	11,724	2,445,293	
	Mar	2,508	2,077	4,959	1,914	11,458	2,577,136	
Total						**33,140 (0.47%)**	**6,968,552**	
After	April	2,506	2,160	4,611	1,983	11,260	2,577,158	7,357,500 Ks (or) 91,939 Baht
	May	2,490	1,780	4,108	1,780	10,158	2,580,010	
	June	2,112	1,680	3,452	1,513	8,757	2,580,106	
Total						**30,175** (**0**.**39**%)	**7,737,274**	
The total goal is no more than 0.40% per production.								

According to Table 6, the loss amount for Unusable broken eggs is considered completely broken and unsuitable for consumption or selling. This calculation was based on the valuation of 1 kg of eggs at the full market price of 3,750 Kyats.

Table 6 The detailed calculation of Unusable Eggs (Completely Broken)

	Total Loss	Kilogram (each egg has 65 grams approximately)	Selling price for 1 KG	The whole loss amount in Kyats
Before	33,140	2154 Kg	3750 Kyats	8,077,500 Ks (100,973 Baht)
After	30,175	1962 Kg	3750 Kyats	7,357,500 Ks (91,939 Baht)
Loss Reduction Amount				**720,000 Ks (9032Baht)**

Discussions

Our study identified several factors contributing to egg breakage on farms, such as inexperienced or unmotivated workers, poor handling practices, and inadequate equipment. These findings align with previous work by Orr et al. (1977), who also identified similar vulnerabilities in egg-handling practices. However, it's important to acknowledge that a broader perspective is necessary to understand the issue of egg breakage fully.

According to research conducted by Mertens et al. (2006), the housing system in which hens are kept can impact the strength of their eggs. The study found that eggs from hens housed in aviary systems were stronger than those from battery-caged hens. This suggests that exploring alternative housing systems that promote animal welfare and egg quality could be beneficial in reducing breakage. The study also highlights the importance of proper handling and processing practices throughout the entire production chain, especially during grading and packing, which significantly affect breakage rates. Therefore, it's crucial to implement appropriate handling procedures and use suitable equipment at the farm level and across all stages of the production chain. Implement proper handling procedures and utilize appropriate equipment at the farm level and across all stages of the production chain.

In addition to the factors we have identified in our study, there may be other possible reasons for egg breakage. These could include factors such as the hens' age, nutrition, and genetics. To minimize egg breakage in various production systems, further research is necessary to fully understand the complex interplay of these various factors and develop comprehensive solutions.

Conclusion and suggestions

The application of DMAIC led to measurable improvements in the egg production process, including reduced issues, better product quality, increased customer satisfaction, and greater efficiency. These accomplishments were achieved through systematic and strategic approaches, including but not limited to streamlining egg handling procedures, extensive worker training, and regular equipment inspections under constant supervision of management. Adopting the DMAIC approach reduced the defective egg rate from 0.47% to 0.39%, which shows notable improvement in sorting out broken eggs and associated losses. On the other hand, real-time data collection was complex, with egg production so fast that limited historical access to data, budget constraints, and time concerns around specific potential improvements were issues the study faced.

Due to financial constraints, farms may need more funds. Therefore, it is not possible to buy advanced egg-handling machines. Furthermore, investigating, choosing, and introducing suitable equipment may not be readily accessible because of ongoing farming activities and obligations. As a result, farms may need to prioritize other improvement strategies. These strategies must be more feasible within the current budget and time constraints. For example, a farm could prioritize existing machinery that might benefit from training programs to boost operator skill levels.

Investing in the proper technical setup and process optimization, including all environmental aspects, is critical to the long-term success, efficiency, and sustainability of Golden Yolk Egg Farm. Even though the farm has made significant progress, there is still room for improvement. One key point to tackle is capital expenditure on up-to-date egg-handling

machines. Although limited by tight budgets and consumer demand, the recognition of their longer-term payoffs is essential. The initial cash outlay for these machines can get excellent results quickly. In addition, automated machinery minimizes material waste and optimizes the process. And then, the farm needs to incorporate sustainability with waste management and recycling. Managing waste correctly can also reduce the environmental impact and improve the cleanliness of inhabited areas—proper disposal and recycling of egg cartons, packaging materials, and farm waste.

Lastly, the ethical aspect of Golden Yolk Egg Farm suggests the development of stress-free chicken farming practices from battery-caged chickens. Notorious for their narrow and restricted quarters, battery cages endanger hen welfare. These efforts improve chicken's welfare and are consistent with what consumers want. So, this change further emphasizes the commitment to sustainability and ethical responsibility. This involves focusing on the farm's vision and building customer loyalty with a shared mission to raise animals while ethically protecting land for long-term success.

New knowledge and the effects on society and communities

The investigation into the egg-breaking incident is a transformation and possibly has national significance. Understanding the primary reasons why Unusable egg breakage has improved as a result of this study also critically discovered effective mitigation strategies. It is important to note that these outcomes support sustainability objectives by reducing resource consumption and waste during egg production. By preserving the environment, this sustainable approach benefits the neighborhood and society.

Breakage reduction measures can also be effectively implemented by adding more staff (or) farm workers. This could encourage local economic stimulation in relatively nearby areas. Furthermore, hiring more employees (or even farm staff) can have positive economic stimulus effects locally. It offers jobs in the local area, which means that the nearby region can get higher wages, thus upgrading living standards in the community.

Improving eggs' security and nutrient content benefits public health by ensuring consumers consistently access nutritious foods. Eggs are economical sources of essential nutrients, making them available to the many as foods that can be afforded even on tight budgets.

Sharing these research findings and implementing best practices can positively influence the exchange of knowledge within the industry. As this information spreads, it is pivotal in fostering trust in our food supply and significantly affects consumer choices. This study can raise egg quality, bolster economic sustainability, promote environmentally responsible practices, boost local employment, enhance public health, and boost consumer confidence in a more robust food production system.

In conclusion, the research in this field has the potential for wide-reaching and enduring impacts across various sectors, encompassing economics, public health, and the trust consumers place in the food they consume.

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