

Review Article

Error-Proofing the Food Industry: A Review of Poka-Yoke Applications for Safety, Quality and Efficiency

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Abstract: The food industry faces persistent challenges in ensuring quality, reducing waste, maintaining operational efficiency, and safeguarding food safety. Poka-Yoke, a Japanese error-proofing methodology, has been widely applied in manufacturing to minimise defects and human errors. This review examines its implementation in the food industry, focusing on its role in improving quality control, reducing process variability, and enhancing productivity. A review of existing literature was conducted, covering applications such as automated error detection, process standardisation, and ergonomic tools, as well as their integration with Lean Six Sigma (LSS) methodologies. The findings show that Poka-Yoke can significantly reduce defects, improve process stability, and enhance worker efficiency across various food sectors. Despite these benefits, the integration of Poka-Yoke into Food Safety Management Systems (FSMS) remains underexplored, with most applications targeting quality improvement rather than comprehensive food safety assurance. Furthermore, research on digitised Poka-Yoke incorporating automation, real-time monitoring, and data analytics is still in its infancy in the food industry. Addressing these gaps presents opportunities for future studies to strengthen FSMS effectiveness, enhance traceability, and ensure proactive error prevention, ultimately advancing food safety and operational excellence in modern food manufacturing.

Keywords: Poka-Yoke; food industry; lean tools; waste reduction; food safety

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1. Introduction

1.1. Challenges and Non-Conformance in Food Safety Management Systems (FSMS)

The food industry carries the essential responsibility of producing safe food while demonstrating transparency in implementing and maintaining food safety measures (Fotopoulos, 2009). To achieve this, many food manufacturing companies adopt Food Safety Management Systems (FSMS), which incorporate tailored control and assurance measures, such as Hazard Analysis and Critical Control Points (HACCP), to uphold food safety standards (Motarjemi & Mortimore, 2005; Teixeira & Sampaio, 2013; Jacxsens *et al.*, 2009).

Despite these systems, foodborne diseases remain a persistent global issue, affecting both developed and developing nations (Asrat *et al.*, 2015). According to the World Health Organisation, 600 million people, nearly 1 in 10 globally, fall ill each year from contaminated food, resulting in 420,000 deaths and 33 million disability-adjusted life years (DALYs) lost (WHO, 2015). Repeated outbreaks occur even in facilities with validated, verified, and audited FSMS (Faour-Klingbeil & Todd, 2020; Nayak & Waterson, 2019; Rustia *et al.*, 2021).

Research shows that FSMS limitations often arise from insufficient sanitation, hygiene deficiencies, poor raw material control, and improper production practices (Ilic *et al.*, 2012; Lehto *et al.*, 2011; Little & Gillespie, 2008; Kussaga *et al.*, 2014). Failures in Good Manufacturing Practices (GMP), mislabelling, and allergen control have also been identified as common causes of food recalls (Soon, 2019). Notably, many of these non-conformances are linked to human error (Jevsnik & Raspor, 2020; Lin & Paez, 2020; Walsh & Leva, 2019; Abidin *et al.*, 2013). This underscores the need for preventive approaches that proactively eliminate errors at their source rather than relying solely on detection and correction.

One such approach is Poka-Yoke, a Japanese error-proofing methodology widely applied in manufacturing to prevent defects and mistakes before they occur. While Poka-Yoke's potential to address human error and strengthen preventive measures is well-established in other industries, its systematic application within FSMS for food safety assurance remains limited. Exploring how Poka-Yoke, particularly in its digitised form, can be integrated into FSMS may offer a practical pathway to reducing non-conformance and enhancing food safety performance globally.

1.2. Poka-Yoke as Error-Proofing Methodology

The concept of Poka-Yoke, which translates to "mistake-proofing" in Japanese, was first introduced by Shigeo Shingo in the 1960s as part of Toyota's production system. Originally developed to minimise human errors in manufacturing, Poka-Yoke has evolved into a widely adopted quality control technique across various industries. The methodology focuses on designing systems, tools, and processes that either prevent errors from occurring or detect and correct them before they lead to defects.

At its core, Poka-Yoke is based on the principle of fail-safe mechanisms, which ensure that mistakes are identified and corrected at the source rather than being passed along the production line. These mechanisms can take various forms, including physical design modifications, sensory alerts, automation, and standardised procedures. By integrating Poka-Yoke into production workflows, companies can enhance efficiency, reduce waste, and improve overall product quality and safety.

While Poka-Yoke has been extensively implemented in manufacturing sectors such as automotive and electronics, its application in the food industry remains an emerging area of study. The complexity of food production processes, combined with stringent safety regulations, presents unique challenges that require tailored error-proofing strategies. Understanding how Poka-Yoke can be adapted to food processing environments is essential for ensuring consistent product quality, minimising contamination risks, and improving compliance with food safety standards.

This review aims to critically examine the implementation of Poka-Yoke within the food industry, evaluating its role in minimising errors, enhancing process efficiency, and ensuring product quality. By identifying key areas where Poka-Yoke has been effectively applied, this review provides insights into its current utilisation and potential for further integration. Furthermore, the review highlights the need for future research on the digitisation of Poka-Yoke, emphasising its potential to enhance automation, real-time monitoring, and predictive capabilities for improved food safety outcomes.

2. Poka-Yoke Techniques

Poka-Yoke can be categorised into two types of action, which are preventive and detection-based. Regulatory functions govern these preventive measures, notifying workers of errors and providing warnings, allowing workers to implement controls as needed. Preventive Poka-Yoke techniques can be categorised into two main types: control-oriented

and warning-oriented (Lazarevic, 2015; Malega, 2018; Zhang, 2014; Prabowo & Aisyah, 2020). Control-oriented Poka-Yoke focuses on preventing errors by physically preventing incorrect operations or actions. It includes methods such as using guides, jigs, or fixtures to ensure proper positioning or alignment, using sensors or switches to detect errors, or implementing mechanisms that allow only correct sequences of operations. On the other hand, warning-oriented Poka-Yoke aims to provide timely feedback or alerts to operators when errors occur, enabling them to take corrective actions. This can involve visual or auditory cues, alarms, or signals that indicate deviations from the standard or expected conditions. Warning-oriented Poka-Yoke helps operators recognise and rectify errors promptly, preventing them from progressing further in the process.

The principle behind detection-based Poka-Yoke is to focus on identifying and minimising errors when it is not possible to eliminate them. Instead of solely relying on error prevention, this approach emphasises the importance of early detection. By implementing detection mechanisms, defects can be identified at an early stage in the process, preventing them from progressing to downstream processes and incurring further costs associated with non-conformance. Therefore, the recommendation is to consider ways to detect errors effectively and reduce their impact if complete error prevention is not feasible. There are 4 poka-yoke techniques (Lazarevic, 2015; Malega, 2018; Zhang, 2014; Prabowo & Aisyah, 2020) as depicted in Figure 1.

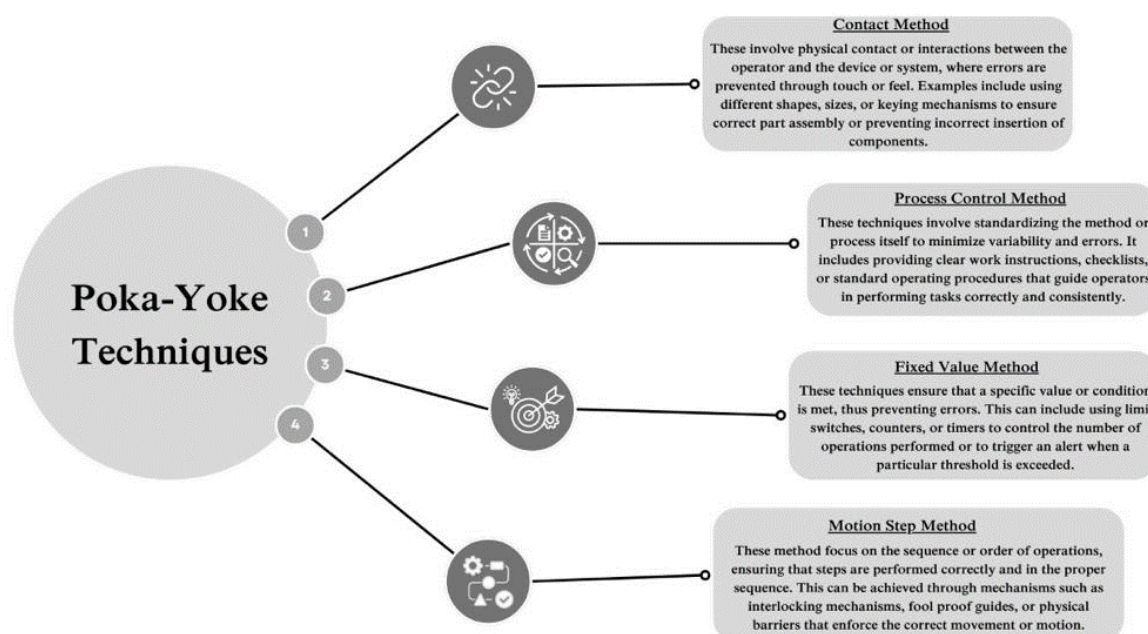


Figure 1. Poka-Yoke Techniques (source: author's own figure)

2.1. Poka-Yoke Application in the Food Industry

The application of poka-yoke in the food industry has been highlighted in several studies. Kiran *et al.* (2023) presents a lean-oriented approach for addressing waste reduction in Turkey's poultry sector, integrating Waste Reduction Management (WRM) and Best-Worst Method (BWM) analysis. The study examines various lean wastes impacting poultry production, proposing targeted solutions to mitigate these inefficiencies through lean tools and practices. Transportation waste, a significant concern identified in this sector, is particularly linked to the use of poka-yoke systems, which play a crucial role in minimising human errors and equipment malfunctions by incorporating preventive warning mechanisms. Specifically, Kiran *et al.* (2023) emphasises the importance of strict adherence to temperature control during the transportation of live animals and perishable food products, as these are highly susceptible to spoilage and contamination if mishandled. The research underscores that the entire transportation chain, from farms to processing facilities and through to distribution networks, requires stringent control measures to uphold food safety and animal welfare standards. By employing Poka-Yoke mechanisms, the poultry sector can enhance the oversight of temperature management in vehicles, thereby reducing risks and improving safety throughout the logistics chain.

One such study was by Aziz *et al.* (2021), which detailed a continuous improvement initiative applying Lean Six Sigma (LSS) methodology to address weight inconsistency in coffee powder packaging within a coffee manufacturing facility in northern Malaysia. Guided by the DMAIC (Define, Measure, Analyse, Improve, Control) framework, the project identifies significant weight variation in coffee powder as a root cause of packaging inconsistency. To address this, the study proposed the implementation of Poka-Yoke, a Lean Manufacturing tool designed to prevent errors by allowing only coffee powder of consistent, acceptable size to enter the packaging process. This Poka-Yoke approach was specifically integrated into the sieving process, ensuring that only appropriately sized powder particles reach the auger filler, which improves auger rotation adjustments and enhances the consistency of packaging weights. Through this intervention, the project demonstrated the potential of Poka-Yoke to support error prevention and process stability in the coffee packaging line.

Similarly, Maheshwar (2013) examined the implementation of a Six Sigma project in an Indian food production plant, addressing the growing issue of defective products, specifically in the production of perishable items like bread (roti). Following the DMAIC methodology, the project identified poor working conditions as a significant factor

contributing to defects. To tackle this, Poka-Yoke was integrated into the manufacturing process as a critical control method, where checkpoints were established at each production stage. Unlike traditional inspection practices, Poka-Yoke requires that internal operators conduct a 100% inspection of every item they produce. This self-inspection process was formalised with a checklist at each stage, which operators were instructed to follow rigorously. The outcomes of this approach included a noticeable reduction in defects, faster production times, standardised procedures, and improved operator accountability and engagement.

Beyond improving defect control, Poka-Yoke has also been leveraged to enhance labour productivity and ergonomic conditions in food packaging. García *et al.* (2021) explored strategies to optimise labour productivity and working conditions in the asparagus packaging process, a critical area for agro-exporters seeking to maintain a competitive edge in the growing asparagus export market. The study focused on a packing station where manual labour was the central point, noting that adequate ergonomic conditions can significantly impact productivity. A physical Poka-Yoke tool was integrated into the process to aid in consistently accurate cutting, creating a more comfortable workstation with added space on the worktable. This tool not only minimised cutting errors but also reduced wrist strain, thereby enhancing worker comfort and safety. Findings demonstrated that incorporating Poka-Yoke led to both an increase in labour productivity and a decrease in physical risk to employees. The study concluded that applying such ergonomic tools not only improves productivity but also fosters a safer and more comfortable work environment.

In addition to packaging and productivity improvements, Poka-Yoke has also been applied to enhance quality assurance in automated retail systems, particularly vending machines. While vending machines provide convenience and accessibility, they present a unique challenge in maintaining product quality, most notably in controlling the sale of expired goods. Unlike conventional retail outlets, where consumers can check expiration dates before purchase, vending machine users typically only see the date after payment, which can lead to dissatisfaction, complaints, and reputational damage to both manufacturers and service providers. Alghozali *et al.* (2016) identified that this issue was often rooted in inadequate stocking, replenishment, and maintenance practices within the vending machine industry, where human oversight errors are common. To address this, the study proposed a Poka-Yoke mechanism in the form of an automatic date-based switch. The system was designed to operate continuously throughout the year, managing two relays that control product dispensing based on the set expiration date. Once the date threshold was reached, the

system automatically disables product release, effectively preventing expired items from being sold.

The intervention demonstrated a proactive approach to error-proofing by eliminating reliance on manual checks and reducing the likelihood of expired goods reaching customers. However, a key limitation was that all products in the machine must share the same expiration date, which restricted flexibility and prevented stocking items with varying shelf lives. This constraint highlights the need for more adaptable designs, potentially through digitised or sensor-based solutions that can track and control expiration dates at the individual product level. By integrating such Poka-Yoke systems, vending machine operators could not only improve consumer trust and service quality but also reduce liability risks associated with expired products. Furthermore, this case illustrated the broader potential of applying error-proofing principles to automated retail systems, where minimal human oversight and continuous operation make proactive quality controls particularly valuable.

Another critical area where Poka-Yoke has been instrumental is in waste reduction in food manufacturing. Food waste remains a significant issue in society, largely due to inefficient management of operational processes in the food industry. Addressing this challenge, Porras *et al.* (2023) focused on reducing raw material waste at a nectar manufacturing facility in Lima, Peru. Their research employed a Green LSS Model, utilising several key tools including Environmental Value Stream Mapping (E-VSM), DMAIC, Poka-Yoke, and Design of Experiments (DOE). A crucial aspect of the study involved the Poka-Yoke method, aimed at preventing errors in the pineapple core removal process. The existing method, which relied on a knife, resulted in significant waste. To enhance efficiency, the researchers proposed replacing the knife with a more effective tool that extracts the core in one piece, rather than chopping the pineapple into multiple sections and removing the core from each piece. This innovative approach aimed to significantly reduce waste and improve operational efficiency in the nectar production process.

Similarly, Mesones-Guillén *et al.* (2019) explored the Poka-Yoke's role in reducing waste and improving efficiency in condiment production. Their study focused on the significant role of the Peruvian export market in the production of dressings and condiments, underscoring the need for improved efficiency in this sector. By integrating lean manufacturing tools, particularly Poka-Yoke techniques and process standardisation, the authors aimed to streamline existing processes and minimise production errors. The Poka-Yoke method was highlighted as a way to lessen the level of oversight required from operators while clarifying the production order and sequence. Following the initial

implementation phase, operators were expected to adopt new guidelines in the subsequent phase. Moreover, the Poka-Yoke tool provides visual prompts for critical activities, especially those affected by process changes. This visual strategy was aimed to decrease process variability and enhance overall production efficiency, effectively addressing waste reduction in the condiment production process.

Poka-Yoke has also been effectively integrated into small and medium-sized enterprises (SMEs) to address waste reduction and efficiency challenges. Aldave-Vasquez *et al.* (2024) investigated a Small Medium Enterprise (SME) in Peru specialising in peanut snack production, where persistent production waste was negatively affecting both operational efficiency and profitability. Recognising that such waste often stems from a combination of human errors, equipment malfunctions, and process inconsistencies, the researchers adopted an integrated improvement strategy using three complementary production management tools: 5S, Total Productive Maintenance (TPM), and Informative Poka-Yoke.

The role of Informative Poka-Yoke in this context was to act as a real-time error prevention and guidance system, ensuring that operators consistently used equipment and instruments within correct parameters. Unlike physical or control Poka-Yoke devices, the informative type focuses on providing timely and clear instructions, warnings, or visual cues to prevent deviations before they result in defects. In this study, the researchers first conducted a comprehensive inspection of each production stage, namely selection, toasting, semi-toasting, and packaging, to identify specific error sources. These included improper machine calibration, inconsistent application of operating procedures, and misinterpretation of measurement specifications.

Based on this analysis, targeted Poka-Yoke interventions were designed to provide precise operational specifications and clarified instrument usage at each stage. For example, visual indicators and step-by-step guides were placed near workstations, while monitoring systems alerted operators when deviations occurred. These measures directly addressed root causes by reducing reliance on memory, minimising subjective judgment, and ensuring that corrective actions could be taken immediately. The impact of this integrated approach was significant. Error rates dropped to 4.25% in the selection process, 2.86% during toasting, and 2.73% in semi-toasting, indicating measurable improvements in process control and product quality. The combination of 5S (workplace organisation), TPM (preventive maintenance), and Informative Poka-Yoke (error prevention through real-time feedback) created a

synergistic effect where organised, well-maintained work environments supported the effective operation of error-proofing systems.

This case highlights that in SMEs, where resources for advanced automation may be limited, low-cost and operator-friendly Poka-Yoke solutions can deliver substantial improvements when systematically integrated with other lean tools. It also suggests that digitising informative Poka-Yoke systems, for example, through sensor-based alerts or automated data logging could further enhance their real-time monitoring capabilities, reduce manual oversight, and strengthen their role within a formal FSMS.

Finally, the application of Poka-Yoke has also extended to the Peruvian food industry's efforts to enhance efficiency in ingredient processing. Huarcaya-Melendez and Platero-Mamani (2023) examined the role of Poka-Yoke in improving efficiency and reducing waste in the cinnamon cleaning process. Their study implemented Poka-Yoke as an error-proofing mechanism to minimise waste generation and enhance process efficiency. Prior to its application, operators required excessive time to clean cinnamon, and a significant portion of raw material was lost due to handling errors. The implementation of Poka-Yoke led to a reduction in waste, improving the overall yield of the process. Additionally, the processing capacity of cinnamon increased, significantly reducing the time required for cleaning operations. These findings underscore the potential of Poka-Yoke in food production, demonstrating its effectiveness in optimising workflows, minimising defects, and contributing to overall process efficiency. The study highlights the need for further research into the integration of Poka-Yoke with digital monitoring systems to enhance real-time error prevention in food safety applications.

Table 1 presents the application of Poka-Yoke in the food industry, categorised based on specific error-proofing techniques. The implementation of Poka-Yoke within food production has demonstrated significant potential in minimising errors, reducing waste, and enhancing process efficiency. Lean-oriented Poka-Yoke strategies have been widely adopted across various sectors, including poultry transport, coffee packaging, and nectar production, where they serve as critical tools for waste reduction and quality control. In the poultry industry, temperature monitoring mechanisms integrated into transportation systems help prevent spoilage, reinforcing Kiran *et al.* (2023) findings on the importance of maintaining strict control during transit. Similarly, in coffee packaging, Poka-Yoke techniques applied to the sieving process have been shown to eliminate weight inconsistencies, ensuring process stability (Aziz *et al.*, 2021).

Table 1. Poka-Yoke Application in the Food Industry

Technique of Poka-Yoke	Application	References
Fixed value method	Quality assurance in vending machines	Alghozali <i>et al.</i> (2016)
	Waste reduction in poultry transportation	Kiran <i>et al.</i> (2023)
	Poka-Yoke mechanism integrated into the sieving process to prevent weight variation during coffee powder packing	Aziz <i>et al.</i> (2021)
	Defect prevention in peanut snack manufacturing	Aldave-Vasquez <i>et al.</i> (2024)
Contact method	Labour productivity and ergonomics in asparagus packaging	García <i>et al.</i> (2021)
	Waste reduction in pineapple nectar production	Porras <i>et al.</i> (2023)
Process control method	Efficiency in condiment production	Mesones-Guillén <i>et al.</i> (2019)
	Defect reduction in bread production	Maheshwar (2013)
	Process efficiency in cinnamon cleaning	Huarcaya-Melendez and Platero-Mamani (2023)

Additionally, ergonomic Poka-Yoke tools, such as specialised work aids in asparagus trimming, contribute to both improved productivity and enhanced worker well-being (García *et al.*, 2021). These tools not only reduce the occurrence of manual errors but also mitigate physical strain, leading to better working conditions and higher-quality output. The collective findings from these studies highlight the effectiveness of Poka-Yoke in fostering reliability and consistency within food manufacturing processes. By integrating error-proofing mechanisms at various stages of production, food manufacturers can enhance operator oversight, streamline operations, and support waste-free, efficient workflows. Consequently, Poka-Yoke emerges as a fundamental component of lean manufacturing principles within the food industry, reinforcing its value in achieving process stability and product quality.

The reviewed case studies collectively demonstrate that Poka-Yoke has been applied across a wide range of food production contexts, consistently contributing to error prevention, process stability, waste reduction, and quality improvement. Successful implementations often share common characteristics, including integration with Lean or Six Sigma methodologies, active operator engagement, attention to ergonomic design, and the use of simple yet effective automation. These factors not only enhance production efficiency but also foster a culture of continuous improvement within manufacturing environments.

Despite these successes, several recurring challenges were observed. Technical integration with existing equipment can be complex, particularly in facilities with legacy

systems. Ensuring consistent operator training and adherence to new procedures remains a critical factor for sustained performance. Additionally, some solutions present design limitations, for instance, the vending machine case, where uniform expiry dates are required, highlighting the need for more adaptable approaches.

A key observation is that most documented applications target improvements in quality and productivity rather than fully embedding Poka-Yoke within FSMS. Furthermore, the adoption of digitised Poka-Yoke leveraging real-time monitoring, data analytics, and automation remains limited. Addressing these gaps presents an opportunity to position Poka-Yoke not only as a quality enhancement tool but also as a proactive, technology-enabled mechanism for strengthening food safety assurance.

3. Discussion

The findings from this review reaffirm the significant role of Poka-Yoke in minimising errors, improving efficiency, and ensuring product quality within the food industry. Applications such as temperature monitoring in poultry transport, weight control in coffee packaging, and ergonomic tools for fresh produce processing demonstrate how Poka-Yoke acts as a preventive mechanism to reduce waste, limit human errors, and enhance process consistency. When integrated with Lean Manufacturing and Six Sigma methodologies, such as DMAIC, Poka-Yoke contributes to process standardisation, greater operational stability, and sustained quality assurance.

However, despite these successes, Poka-Yoke adoption in the food industry faces several barriers. First, cost considerations can deter smaller enterprises, particularly SMEs, from investing in advanced or customised error-proofing systems. While simple physical devices are relatively inexpensive, more sophisticated or automated versions require higher capital expenditure. Second, technical expertise is often lacking, especially in regions where lean manufacturing principles are not yet widely embedded in food sector training. Without adequate skills in design, integration, and maintenance, Poka-Yoke systems may be underutilised or incorrectly applied. Third, scalability issues arise when adapting solutions across different product lines, production volumes, or facility layouts, highlighting the need for adaptable, modular designs.

From an international perspective, variations in regulatory frameworks, infrastructure readiness, and industry maturity also influence adoption rates. For example, countries with strict traceability and labelling requirements (e.g., within the EU or under FDA oversight in the United States) may have stronger incentives to integrate advanced error-proofing systems,

whereas in developing regions, limited enforcement and resource constraints can slow uptake. Furthermore, policy challenges such as the absence of explicit guidelines for incorporating Poka-Yoke into FSMS create ambiguity about its role in regulatory compliance, particularly for digitised systems that may raise data privacy, interoperability, or cybersecurity concerns.

Lastly, while most current Poka-Yoke applications remain mechanical or manual, the global food industry is moving toward digital transformation, emphasising automation, real-time monitoring, and data-driven decision-making. The limited adoption of digitised Poka-Yoke, which could integrate sensors, machine vision, and Internet of Things (IoT)-based alerts, represents both a gap and an opportunity. Future research should therefore not only explore technological integration but also address the economic, technical, and regulatory enablers that can make Poka-Yoke scalable, adaptable, and globally relevant in modern food manufacturing.

4. Conclusions

Poka-Yoke has proven to be a valuable tool in enhancing food production efficiency, reducing process variability, and minimising human errors. It has successfully addressed challenges such as waste reduction, defect prevention, and worker productivity. However, despite these advancements, existing Poka-Yoke applications remain largely mechanical and manual, limiting their adaptability and responsiveness in increasingly complex and automated food production environments.

To fully optimise its potential, future research should explore digitised Poka-Yoke solutions that incorporate emerging technologies such as AI-driven quality control, IoT-enabled sensors for real-time food safety tracking, and machine vision for automated defect detection. These technologies can facilitate continuous monitoring, predictive maintenance, and data-driven decision-making, aligning Poka-Yoke with Industry 4.0 objectives.

From a practical standpoint, managers could leverage on digitised Poka-Yoke to reduce dependency on manual inspections, improve traceability, and standardise quality control across production sites. Policymakers, on the other hand, could develop guidelines and incentives to encourage the integration of such systems into FSMS, ensuring compliance with increasingly stringent regulatory requirements.

By transitioning from a static error-prevention mechanism to a dynamic, technology-enabled system, Poka-Yoke can strengthen food safety, enhance operational efficiency, and position food manufacturers to meet both current and future challenges in a competitive global market.

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References

- Abidin, U. F. U. Z., Arendt, S. W., & Strohbehn, C. H. (2013). Exploring the culture of food safety: the role of organizational influencers in motivating employees' safe food-handling practices. *Journal of Quality Assurance in Hospitality & Tourism*, 14(4), 321–343. <https://doi.org/10.1080/1528008X.2013.802587>
- Aldave-Vasquez, Y., Morales-Vargas, S., & Corzo-Chavez, J. (2024). Production management model for waste reduction using 5s, Tpm and Poka Yoke tools in a peanut snack manufacturing company. In *Proceedings of the World Congress on Mechanical, Chemical, and Material Engineering, Barcelona, Spain* (pp. 22–24).
- Alghozali, F. I., Jamaludin, R., & Bahaudin, A. Y. (2016). Enhancing quality of service: A conceptual Poka-Yoke approach. *Journal of Technology and Operations Management*, 11(2), 47–56.
- Asrat M., Andualem H., Worku T., *et al.* (2015). Assessment of the sanitary conditions of catering establishments and food safety knowledge and practices of food handlers in Addis Ababa University students' cafeteria science, *Journal of Public Health*, 3(5), 733–743. <https://doi.org/10.11648/j.sjph.20150305.30>
- Aziz, N. A. N., Ahmad, R., Mustafa, S. A., *et al.* (2021). Application of lean six sigma methodology to improve the weight inconsistency problem of coffee powder packaging. *Jurnal Sistem dan Manajemen Industri*, 5(2), 74–86. <https://doi.org/10.30656/jsmi.v5i2.3729>
- Faour-Klingbeil, D., & Todd, E. (2020). Prevention and control of foodborne diseases in Middle East North African countries: Review of national control systems. *International Journal of Environmental Research and Public Health*, 17(1), 70. <https://doi.org/10.3390/ijerph17010070>
- Fotopoulos, C.V., Kafetzopoulos, D.P., & Psomas, E.L. (2009). Assessing the critical factors and their impact on the effective implementation of a food safety management system. *International Journal of Quality & Reliability Management*, 26, 894–910. <https://doi.org/10.1108/02656710910995082>
- García, C. S., Marroquín, A. C., Macassi, I. A., *et al.* (2021). Proposal of Work Study and Anthropometric Workstation Redesign to Increase the Productivity on Asparagus Industries. In *2021 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)* (pp. 760–764). IEEE. <https://doi.org/10.1109/IEEM50564.2021.9672974>
- Huarcaya-Melendez, V., Platero-Mamani, A. (2023). Production model based on lean tools and SLP to increase labor productivity in companies in the food industry. In *Industrial Engineering and Applications* (pp. 651–660). IOS Press. <https://doi.org/10.3233/ATDE230092>

- Ilic, S., Odomeru, J., LeJeune, J. T. (2008). Coliforms and prevalence of *Escherichia coli* and foodborne pathogens on minimally processed spinach in two packing plants. *Journal of Food Protection*, 71(12), 2398–2403. <https://doi.org/10.4315/0362-028X-71.12.2398>
- Jacxsens, L., Kussaga, J., Luning, P. A., *et al.* (2009). A microbial assessment scheme to measure microbial performance of food safety management systems. *International Journal of Food Microbiology*, 134(1–2), 113–125. <https://doi.org/10.1016/j.ijfoodmicro.2009.02.018>
- Jevšnik, M., & Raspor, P. (2020). The human factor as a trigger of food safety culture within food networks: the review. *Acta Microbiologica Bulgarica*, 36(4), 115–131.
- Kiran, E., Ozkan-Ozen, Y. D., & Ozturkoglu, Y. (2023). A solution approach proposal with a lean perspective for the poultry sector with WRM and BWM integration. *International Journal of Quality & Reliability Management*, 41(5), 1290–1307. <https://doi.org/10.1108/IJQRM-03-2023-0105>
- Kussaga, J. B., Jacxsens, L., Tiisekwa, B. P., *et al.* (2014). Food safety management systems performance in African food processing companies: A review of deficiencies and possible improvement strategies. *Journal of the Science of Food and Agriculture*, 94(11), 2154–2169. <https://doi.org/10.1002/jsfa.6575>
- Lazarevic, M., Mandic, J., Sremcev, N., *et al.* (2019). A systematic literature review of Poka-Yoke and novel approach to theoretical aspects. *Strojniski Vestnik/Journal of Mechanical Engineering*, 65(7–8), 454–467. <https://doi.org/10.5545/sv-jme.2019.6056>
- Lehto, M., Kuisma, R., Määttä, J., *et al.* (2011). Hygienic level and surface contamination in fresh-cut vegetable production plants. *Food Control*, 22(3–4), 469–475. <https://doi.org/10.1016/j.foodcont.2010.09.029>
- Lin, N., & Paez, P. (2020). Leading by example: A three-wave sequential mixed method food safety study. *International Journal of Hospitality Management*, 87, 102463. <https://doi.org/10.1016/j.ijhm.2020.102463>
- Little, C. L., & Gillespie, I. A. (2008). Prepared salads and public health. *Journal of Applied Microbiology*, 105(6), 1729–1743. <https://doi.org/10.1111/j.1365-2672.2008.03801.x>
- Maheshwar, G. (2013). Application of Six Sigma in a small food production plant of India: a case study. *International Journal of Six Sigma and Competitive Advantage*, 7(2–4), 168–180. <https://doi.org/10.1504/IJSSCA.2012.053446>
- Malega, P. (2018). Poka–Yoke–solution to human errors in the production process. *International Journal of Business Management and Technology*, 2(5), 207–213.
- Mesones-Guillén, A., Palacios-Jesús, L., Carvallo-Munar, E., *et al.* (2019). Lean manufacturing model adapted for waste reduction in peruvian condiment production agri-businesses. In *Brazilian Technology Symposium* (pp. 381–389). Springer. https://doi.org/10.1007/978-3-030-57548-9_35
- Motarjemi, Y., Mortimore, S. (2005). Industry’s need and expectations to meet food safety, 5th International meeting, Noordwijk food safety and HACCP Forum, 9–10 December 2002. *Food Control*, 16(6), 523e529. <https://doi.org/10.1016/j.foodcont.2004.10.014>

- Nayak, R., & Waterson, P. (2016). ‘When food kills’: A socio-technical systems analysis of the UK Pennington 1996 and 2005 *E. coli* O157 outbreak reports. *Safety Science*, 86, 36–47. <https://doi.org/10.1016/j.ssci.2016.02.007>
- Ortiz Porras, J. E., Bancovich Erquínigo, A. M., Candia Chávez, T. C., *et al.* (2023). Green Lean Six Sigma model for waste reduction of raw material in a nectar manufacturing company of Lima, Peru. *Journal of Industrial Engineering and Management*, 16(2), 169–185. <https://doi.org/10.3926/jiem.4916>
- Prabowo, R. F., & Aisyah, S. (2020). Poka-Yoke Method implementation in industries: A systematic. *Indonesian Journal of Industrial Engineering and Management*, 1(1), 12–24. <https://doi.org/10.22441/ijiem.v1i1.8803>
- Rustia, A. S., Tan, M. A. P., Guiriba, D. N. S., *et al.* (2021). Defining risk in food safety in the Philippines. *Current Research in Nutrition and Food Science Journal*, 9(1), 233–257. <https://doi.org/10.12944/CRNFSJ.9.1.23>
- Soon, J. M., Brazier, A. K., & Wallace, C. A. (2020). Determining common contributory factors in food safety incidents—A review of global outbreaks and recalls 2008–2018. *Trends in Food Science & Technology*, 97, 76–87. <https://doi.org/10.1016/j.tifs.2019.12.030>
- Teixeira, S., & Sampaio, P. (2013). Food safety management system implementation and certification: survey results. *Total Quality Management & Business Excellence*, 24(3–4), 275–293.
- Walsh, C., & Leva, M. C. (2019). A review of human factors and food safety in Ireland. *Safety Science*, 119, 399–411. <https://doi.org/10.1016/j.ssci.2018.07.022>
- World Health Organization (WHO). (2015). *WHO estimates of the global burden of foodborne diseases: Foodborne Disease Burden Epidemiology Reference Group 2007–2015*. World Health Organization. Retrieved from <https://apps.who.int/iris/handle/10665/199350>
- Zhang, A. (2014). Quality improvement through Poka–Yoke: from engineering design to information system design. *International Journal of Six Sigma and Competitive Advantage*, 8(2), 147–159. <https://doi.org/10.1504/IJSSCA.2014.064260>

