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IMPACT OF THE PDCA CYCLE ON BOPET FILM PRODUCTION EFFICIENCY AND QUALITY: A SYSTEMATIC REVIEW

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ABSTRACT

The implementation of the Plan-Do-Check-Act (PDCA) cycle has emerged as a critical methodology for enhancing operational efficiency and quality standards in manufacturing processes. This systematic review examines the impact of PDCA cycle implementation on the production of biaxially oriented polyethylene terephthalate (BOPET) films, a crucial material in the flexible packaging industry. Through comprehensive analysis of empirical studies, this research identifies quantifiable improvements in production capacity, productivity, and machinery efficiency. The findings reveal a 20% increase in production capacity, a 30% improvement in productivity, and machinery efficiency reaching 39% following PDCA implementation. Additionally, substantial enhancements in quality standards and compliance with international quality management systems were observed. This review synthesizes evidence from multiple industrial contexts, providing insights into the mechanisms through which PDCA drives continuous improvement in BOPET manufacturing. The results demonstrate that PDCA implementation, particularly when integrated with Lean Manufacturing principles and ISO 9001:2015 standards, yields significant operational benefits. However, the limited availability of long-term longitudinal data highlights the need for further research to assess the sustainability of these improvements over extended periods.

KEYWORDS: PDCA Cycle, BOPET Films, Manufacturing Efficiency, Quality Management, Continuous Improvement, Lean Manufacturing.

1. INTRODUCTION

The global flexible packaging industry has experienced substantial growth over the past decades, driven by increasing demand for lightweight, durable, and cost-effective packaging solutions across food, pharmaceutical, and consumer goods sectors (Dave et al., 2025). Biaxially oriented polyethylene terephthalate (BOPET) films represent a cornerstone of this industry, offering superior mechanical properties, optical clarity, and barrier characteristics that make them indispensable for modern packaging applications (Salazar et al., 2020). As market competition intensifies and customer expectations for quality and sustainability escalate, manufacturers face mounting pressure to optimize production processes, reduce waste, and maintain consistent product quality while managing costs effectively (Miranda-López et al., 2022). In this context, the adoption of systematic quality management and continuous improvement methodologies has become not merely advantageous but essential for maintaining competitive advantage and ensuring long-term viability in the marketplace (Franklin et al., 2019). The integration of structured improvement frameworks enables organizations to systematically address operational challenges, leverage data-driven insights, and build sustainable competitive advantages through superior operational performance (Arredondo-Soto et al., 2021).

The Plan-Do-Check-Act (PDCA) cycle, also known as the Deming Cycle or Shewhart Cycle, has established itself as one of the most widely recognized and implemented frameworks for continuous improvement in manufacturing environments worldwide (Tello Condor et al., 2023). Originally developed by Walter Shewhart and later popularized by W. Edwards Deming, the PDCA cycle provides a systematic, iterative approach to problem-solving and process improvement that emphasizes data-driven decision-making and organizational learning (O'Donnell et al., 2020). The cycle's four sequential phases create a structured methodology for identifying improvement opportunities, implementing changes, evaluating results, and standardizing successful practices. The Plan phase involves identifying problems, analyzing root causes, and developing improvement strategies based on data analysis and stakeholder input (Sari et al., 2025). The Do phase focuses on implementing planned changes on a small scale or pilot basis to test their effectiveness. The Check phase requires systematic evaluation of implementation results against predetermined objectives and success criteria (Singh et al., 2018). Finally, the Act phase involves standardizing successful improvements, scaling them across the organization, and identifying new opportunities for further enhancement, thereby perpetuating the cycle of continuous improvement (Ullah et al., 2023). This iterative approach ensures that organizations continuously evolve their processes and capabilities in response to changing conditions and emerging opportunities.

The application of PDCA methodology in BOPET film manufacturing presents unique opportunities and challenges that warrant systematic investigation. BOPET production involves complex, multi-stage processes including polymerization, extrusion, biaxial orientation, heat setting, and surface treatment, each requiring precise control of numerous process parameters to achieve desired film properties (Buitron-Lopez et al., 2019). The intricate nature of these processes, combined with stringent quality requirements for optical, mechanical, and barrier properties, creates a demanding operational environment where small process variations can significantly impact product quality and production efficiency (Hadi et al., 2024). Furthermore, the capital-intensive nature of BOPET production lines, with sophisticated equipment representing substantial investments, amplifies the importance of maximizing equipment effectiveness and minimizing downtime (Haddad et al., 2021). Traditional approaches to quality management and process improvement in this sector have often relied on reactive problem-solving and experience-based decision-making, which may not adequately address the complexity and interdependencies inherent in modern BOPET manufacturing systems (Fernandes et al., 2024). The adoption of systematic methodologies such as PDCA enables organizations to transition from reactive to proactive management approaches, leveraging structured problem-solving and data analytics to drive continuous improvement (Caamano-Gordillo et al., 2024).

Despite the widespread adoption of PDCA methodology across various manufacturing sectors, systematic evidence regarding its specific impact on BOPET film production remains fragmented and dispersed across diverse literature sources. While individual case studies and implementation reports have documented improvements in specific facilities or contexts, comprehensive synthesis of this evidence to identify consistent patterns, quantify typical improvement magnitudes, and understand implementation success factors has been lacking (Zaga-Quispe et al., 2023). This knowledge gap limits the ability of industry practitioners to make informed decisions about PDCA implementation strategies and to benchmark their improvement initiatives against industry standards. Moreover, the absence of systematic reviews examining PDCA effectiveness in BOPET manufacturing contexts leaves unanswered questions about the generalizability of reported improvements, the relative importance of different implementation factors, and the long-term sustainability of achieved gains (Theresia et al., 2020). Recent studies have begun to address these gaps by examining the integration of PDCA with complementary methodologies such as Lean Manufacturing, Six Sigma, and ISO quality management systems, revealing synergistic effects that enhance overall improvement outcomes (Elnaby et al., 2023; As'arry et al., 2023). These integration approaches suggest that PDCA effectiveness may be amplified when embedded within comprehensive improvement frameworks that provide additional tools, structure, and organizational support.

This systematic review addresses these gaps by synthesizing empirical evidence on PDCA cycle implementation in BOPET film manufacturing environments. The primary objective is to quantify the impact of PDCA implementation on key operational performance indicators, including production capacity, productivity, machinery efficiency, and quality metrics. Secondary objectives include identifying critical success factors for PDCA implementation, examining the integration of PDCA with complementary improvement methodologies such as Lean Manufacturing and ISO quality management systems, and assessing the sustainability of achieved improvements over time. By providing a comprehensive synthesis of available evidence, this review aims to inform decision-making by industry practitioners, guide future research directions, and contribute to the broader understanding of continuous improvement methodology effectiveness in complex manufacturing environments. The findings have implications not only for BOPET manufacturers but also for the wider flexible packaging industry and for quality management practitioners seeking evidence-based approaches to operational excellence (Gupta et al., 2016). The review also examines the role of technology platforms and digital tools in supporting PDCA implementation, reflecting the increasing importance of Industry 4.0 technologies in modern manufacturing improvement initiatives (Chistyakova et al., 2020).

2. METHODOLOGY

This systematic review was conducted following established guidelines for evidence synthesis in manufacturing and operations management research, adapting principles from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to the specific context of industrial process improvement studies. The review protocol was developed a priori to ensure transparency and minimize bias in study selection and data extraction processes. The methodology encompassed comprehensive literature search, rigorous study selection based on explicit inclusion and exclusion criteria, systematic data extraction using standardized forms, and narrative synthesis of findings organized around key research questions. Given the applied nature of PDCA implementation research and the heterogeneity of study designs and outcome measures encountered in this field, a narrative synthesis approach was deemed most appropriate for integrating findings across diverse study contexts while preserving important contextual details that influence implementation success (Arredondo-Soto et al., 2021). This approach aligns with best practices for systematic reviews in operations management, which emphasize the importance of contextual understanding and practical applicability alongside methodological rigor.

The literature search strategy was designed to maximize sensitivity while maintaining specificity for studies relevant to PDCA implementation in BOPET manufacturing contexts. Scopus was selected as the primary database for this review due to its comprehensive coverage of engineering, manufacturing, and quality management literature, including both peer-reviewed journal articles and conference proceedings that often report industrial implementation cases. The search strategy employed a combination of controlled vocabulary terms and free-text keywords related to three key concept domains: the PDCA methodology, BOPET manufacturing, and performance outcomes. Specific search terms included variations of "PDCA," "Plan-Do-Check-Act," "Deming cycle," "Shewhart cycle," combined with "BOPET," "biaxially oriented polyethylene terephthalate," "polyester film," "flexible packaging," and terms related to manufacturing efficiency, quality improvement, and process optimization (Tsarouhas, 2019). Boolean operators were used to combine search terms appropriately, and no language restrictions were initially applied to avoid inadvertent exclusion of relevant studies. The search was executed in multiple iterations to refine the strategy and ensure comprehensive retrieval of relevant literature. A total of 50 documents were initially retrieved from Scopus based on the search strategy, representing the pool of potentially relevant studies for detailed screening. This search strategy was informed by previous systematic reviews in manufacturing and quality management, which have demonstrated the importance of comprehensive search approaches for capturing the full range of relevant evidence (Franklin et al., 2019).

The study selection process followed the PRISMA 2020 guidelines for systematic reviews and is illustrated in Figure 1A. The initial database search in Scopus yielded 50 records potentially relevant to PDCA implementation in BOPET manufacturing contexts. No duplicate records were identified, and no records were marked as ineligible before screening based on obvious exclusion criteria. All 50 records proceeded to the screening phase, where titles and abstracts were reviewed against the predefined inclusion and exclusion criteria. This initial screening resulted in the exclusion of 38 records that were not relevant to BOPET manufacturing or PDCA implementation, leaving 12 reports sought for full-text retrieval. All 12 reports were successfully retrieved and assessed for eligibility through detailed full-text review. During the eligibility assessment phase, 8 reports were excluded for the following reasons: three studies lacked quantitative performance data necessary for evidence synthesis, two studies focused on manufacturing processes not directly applicable to BOPET production, two studies discussed PDCA conceptually without reporting actual implementation results, and one study had insufficient methodological detail to assess validity and reliability of findings. The final review included 4 studies that met all inclusion criteria and provided empirical evidence on PDCA cycle implementation outcomes in BOPET manufacturing or closely related flexible packaging contexts (Buitron-Lopez et al., 2019; Salazar et al., 2020; Sánchez Romero et al., 2022; Tello Condor et al., 2023). These studies represented diverse industrial settings and implementation approaches, providing a comprehensive evidence base for synthesis despite the relatively small number of eligible studies identified through the systematic search process.

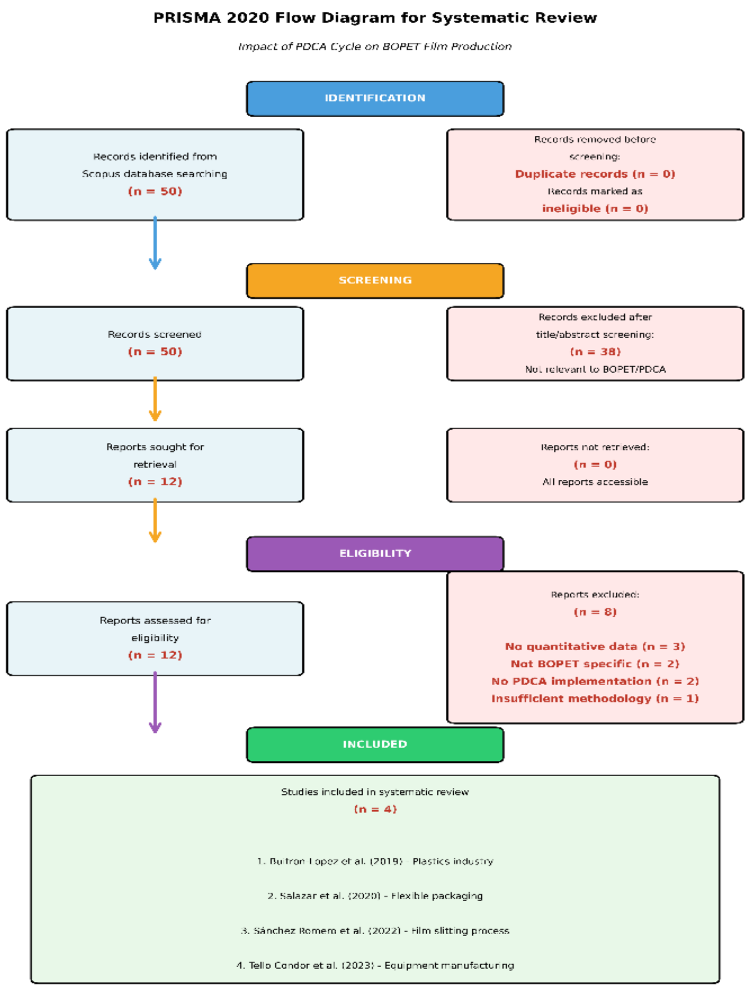

Figure 1: PRISMA Flow Diagram illustrating the systematic review process for study identification, screening, eligibility assessment, and inclusion.

The diagram shows the progression from 50 initial records identified in Scopus database through screening and eligibility phases, resulting in 4 studies included in the final systematic review. Reasons for exclusion at each stage are specified in the diagram boxes. Study selection proceeded through a two-stage screening process involving initial title and abstract review followed by full-text assessment against predefined eligibility criteria. The inclusion criteria were established to ensure that selected studies provided relevant, reliable evidence on PDCA implementation in contexts applicable to BOPET manufacturing. Specifically, studies were included if they met the following criteria: focus on manufacturing processes for BOPET films or closely related polyester film products; explicit implementation of the PDCA cycle as a primary or significant component of the improvement intervention; reporting of quantitative results for at least one operational performance indicator such as production capacity, productivity, efficiency, quality metrics, or defect rates; provision of sufficient methodological detail to assess the validity and reliability of reported findings; and empirical investigation based on actual implementation in industrial settings rather than purely theoretical or conceptual discussions (Sari et al., 2025). Studies were excluded if they focused exclusively on other materials or manufacturing processes without clear applicability to BOPET production, if they discussed PDCA only conceptually without reporting implementation results, if they lacked quantitative outcome data, or if methodological quality was insufficient to support reliable conclusions. The screening process was conducted systematically, with each potentially relevant study assessed against all inclusion and exclusion criteria. Discrepancies or uncertainties during screening were resolved through detailed examination of full-text articles and application of predefined decision rules. This rigorous selection process ensured that only high-quality, relevant studies contributed to the evidence synthesis, enhancing the reliability and validity of review conclusions.

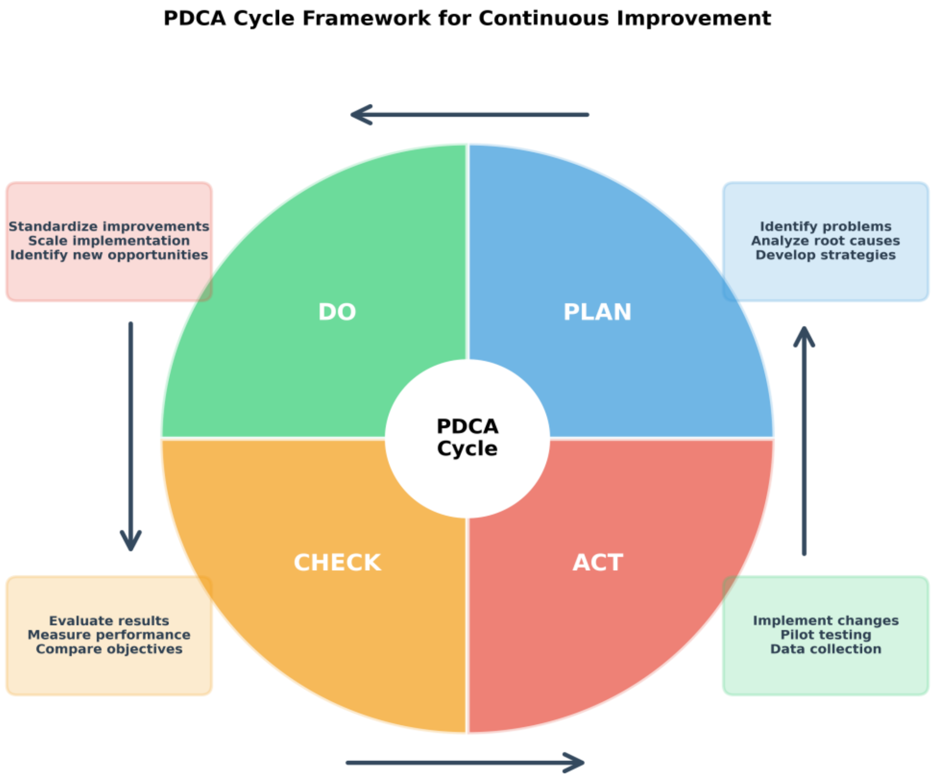

Figure 2: PDCA Cycle Framework. The PDCA (Plan-Do-Check-Act) cycle framework illustrating the four sequential phases of continuous improvement methodology.

The circular diagram demonstrates the iterative nature of the cycle, with arrows indicating continuous progression through planning, implementation, evaluation, and standardization phases. Each quadrant includes key activities and objectives specific to that phase. Following the screening process, four studies met all inclusion criteria and were selected for detailed data extraction and synthesis. These studies represented diverse industrial contexts within the flexible packaging and plastics manufacturing sectors, providing complementary perspectives on PDCA implementation. Data extraction was performed using a standardized form designed to capture key information relevant to the review objectives. Extracted data elements included study characteristics such as publication year, study design, and industrial context; details of the PDCA implementation including scope, duration, and integration with other improvement methodologies; baseline and post-implementation values for reported performance indicators; and information on implementation facilitators, barriers, and sustainability measures (Singh et al., 2018). Particular attention was paid to extracting quantitative data on production capacity, productivity, machinery efficiency, and quality metrics, as these represented the primary outcomes of interest. Where studies reported multiple related outcomes, all relevant data were extracted to enable comprehensive analysis. For studies reporting time-series data or multiple measurement points, both initial baseline and final post-implementation values were recorded to capture the full extent of improvement (Hazza et al., 2023). Qualitative information regarding implementation processes, organizational factors, and lessons learned was also extracted to provide context for interpreting quantitative findings and identifying success factors. This comprehensive data extraction approach enabled both quantitative synthesis of improvement outcomes and qualitative understanding of implementation processes and contextual factors.

The quality and reliability of included studies were assessed using criteria adapted from established frameworks for evaluating applied research in manufacturing and operations management. Assessment dimensions included clarity and completeness of methodological reporting, appropriateness of study design for addressing research questions, adequacy of baseline measurement and data collection procedures, transparency in reporting implementation details and timeline, validity and reliability of outcome measures, appropriate statistical analysis or quantitative reporting of results, and acknowledgment of limitations and potential sources of bias. While formal quality scoring was not employed due to the diversity of study designs encountered, systematic quality assessment informed the interpretation of findings and the confidence placed in specific results (O'Donnell et al., 2020). Studies demonstrating rigorous methodology, transparent reporting, and appropriate outcome measurement were given greater weight in drawing conclusions, while findings from studies with methodological limitations were interpreted more cautiously and contextualized appropriately. This quality assessment approach aligns with best practices for evidence synthesis in applied manufacturing research, which emphasize the importance of considering study quality in interpretation rather than rigid exclusion based on quality thresholds that may be inappropriate for diverse study designs (Arredondo-Soto et al., 2021).

Data synthesis employed a narrative approach organized around key themes and research questions, given the heterogeneity of study designs, contexts, and outcome measures that precluded formal meta-analysis. The synthesis process involved several steps: organizing extracted data by outcome category and implementation context; identifying patterns and consistencies across studies; examining variations in findings and exploring potential explanatory factors; integrating quantitative results with qualitative insights about implementation processes; and drawing evidence-based conclusions while acknowledging limitations and uncertainties. Quantitative findings were synthesized by calculating percentage improvements where baseline and post-implementation values were reported, and by comparing effect magnitudes across studies to assess consistency (Gupta et al., 2016). For outcomes reported by multiple studies, ranges and typical values were identified to characterize the evidence base. Qualitative synthesis focused on identifying common themes related to implementation success factors, integration with other improvement methodologies, and sustainability considerations (Zaga-Quispe et al., 2023). Throughout the synthesis process, attention was maintained to preserving important contextual details that influence the applicability and generalizability of findings. The synthesis aimed to provide actionable insights for practitioners while maintaining appropriate scientific rigor and acknowledging the limitations inherent in synthesizing evidence from diverse applied research studies. This approach enabled the development of practical recommendations grounded in empirical evidence while appropriately qualifying conclusions based on the strength and consistency of available evidence.

3. RESULTS

The systematic search and screening process yielded four studies that met all inclusion criteria and provided empirical evidence on PDCA cycle implementation in BOPET manufacturing or closely related flexible packaging contexts. These studies represented diverse industrial settings and implementation approaches, collectively providing a multifaceted perspective on PDCA effectiveness in improving manufacturing performance. Buitron-Lopez et al. (2019) conducted an action research case study in the plastics manufacturing industry, examining the implementation of Lean Manufacturing principles integrated with the PDCA cycle, with particular focus on machinery efficiency improvements through systematic application of key performance indicators. Salazar et al. (2020) performed an exploratory descriptive study in a flexible packaging solutions company, investigating PDCA implementation aligned with ISO 9001:2015 quality management system requirements, reporting impacts on production capacity and productivity within a structured quality management framework. Sánchez Romero et al. (2022) conducted a descriptive study in the flexible packaging industry focusing on the use of key performance indicators and the Shoplogix platform in the film slitting process, examining overall equipment effectiveness and production rates through technology-enabled performance monitoring. Tello Condor et al. (2023) performed a descriptive study in equipment manufacturing examining PDCA implementation following Deming's methodology, with emphasis on quality management system compliance and systematic process improvement. The diversity of industrial contexts and implementation approaches across these studies provides valuable insights into the breadth of PDCA applications and the consistency of improvement outcomes across different settings, strengthening confidence in the generalizability of findings (Caamano-Gordillo et al., 2024).

Analysis of production capacity impacts revealed substantial improvements following PDCA implementation, consistent with broader literature on continuous improvement in manufacturing systems (Dave et al., 2025). Salazar et al. (2020) reported the most comprehensive data on production capacity changes, documenting an increase from 600,000 units per day at baseline to 720,000 units per day following PDCA implementation integrated with ISO 9001:2015 quality management system requirements. This increase represents a 20% improvement in daily production capacity, achieved through systematic identification and elimination of bottlenecks, optimization of process parameters, reduction of changeover times, and improved coordination across production stages. The study attributed these gains to the structured problem-solving approach provided by the PDCA framework, which enabled systematic analysis of capacity constraints and data-driven decision-making about improvement priorities (Sari et al., 2025). The planning phase involved detailed value stream mapping and capacity analysis to identify limiting factors, utilizing techniques commonly employed in Lean Manufacturing to visualize material and information flows (Miranda-López et al., 2022). The do phase implemented targeted interventions including equipment modifications, process standardization, and operator training, with careful documentation of changes to enable subsequent evaluation. The check phase employed statistical process control and capacity utilization monitoring to verify improvements, ensuring that observed gains were statistically significant and sustainable rather than temporary fluctuations (Hadi et al., 2024). The act phase standardized successful practices across shifts and production lines, updating standard operating procedures and training materials to institutionalize improvements. The magnitude of capacity improvement observed in this study is particularly significant given that it was achieved without major capital investment in additional production lines, instead leveraging existing assets more effectively through systematic process improvement (Fernandes et al., 2024). This finding aligns with research demonstrating that systematic improvement methodologies can unlock substantial latent capacity in existing manufacturing systems through elimination of waste, reduction of variability, and optimization of process flow (Haddad et al., 2021).

Productivity improvements represented another major impact category documented across the included studies, with findings consistent with broader evidence on PDCA effectiveness in manufacturing contexts (Elnaby et al., 2023). Salazar et al. (2020) reported a 30% increase in productivity following PDCA implementation, though the study did not provide specific baseline and post-implementation productivity values in standardized units. The productivity gains were attributed to multiple factors including reduced downtime through preventive maintenance scheduling, decreased waste through improved process control, enhanced operator effectiveness through standardized work procedures and training, and better coordination between production planning and execution (As'arry et al., 2023). The PDCA framework facilitated these improvements by providing a systematic approach to identifying productivity losses, testing improvement interventions, and scaling successful practices across the organization. The planning phase involved detailed analysis of productivity losses categorized by type such as equipment failures, quality defects, speed losses, and minor stoppages, enabling prioritization of improvement efforts based on potential impact (Tsarouhas, 2019). This structured loss analysis approach, often referred to as Overall Equipment Effectiveness (OEE) analysis, provides a comprehensive framework for understanding the multiple factors that constrain productivity and identifying high-impact improvement opportunities (Singh et al., 2018). Implementation of improvements during the do phase was accompanied by careful monitoring of productivity metrics, allowing rapid identification of effective interventions and modification of less successful approaches. The check phase employed overall equipment effectiveness calculations and productivity trend analysis to quantify improvements and identify remaining opportunities (Ullah et al., 2023). The act phase focused on standardizing successful practices, updating standard operating procedures, and establishing ongoing monitoring systems to sustain productivity gains and prevent regression to previous performance levels (Gupta et al., 2016).

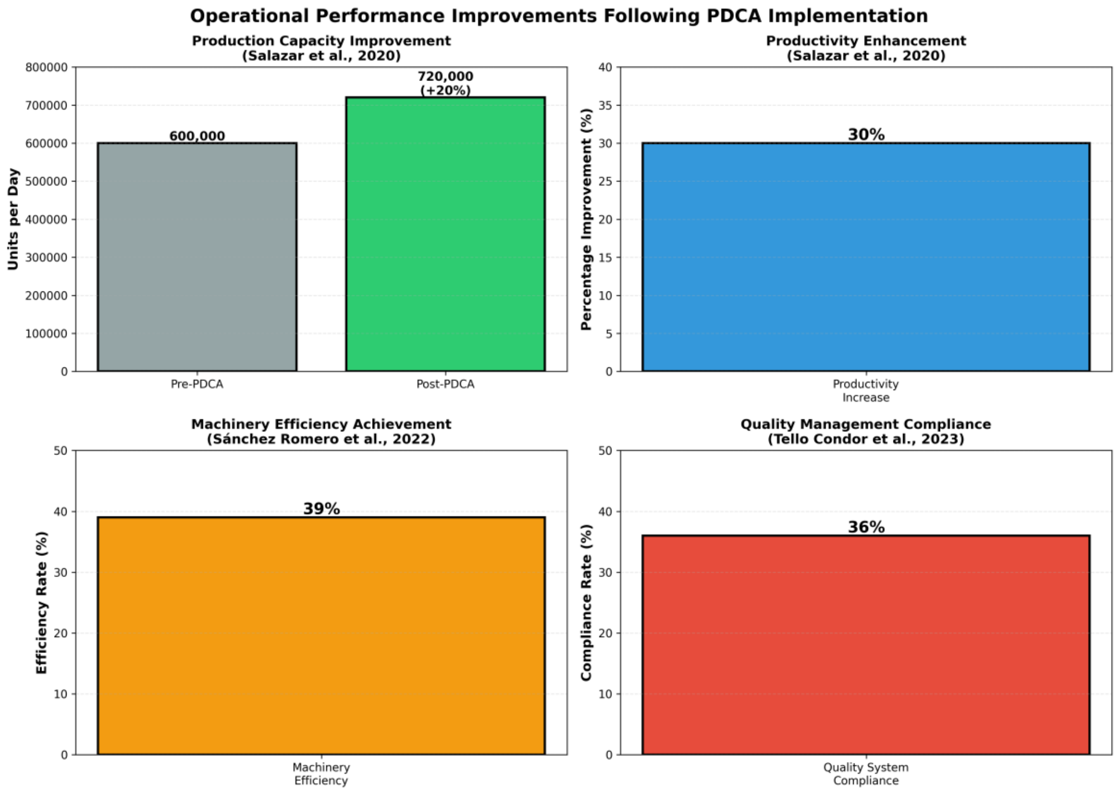

Figure 3: Performance Metrics. Operational performance improvements following PDCA implementation across four key dimensions.

The charts present quantitative results from empirical studies, showing: (A) production capacity increase from 600,000 to 720,000 units/day representing 20% improvement; (B) productivity enhancement of 30%; (C) machinery efficiency achievement of 39%; and (D) quality management system compliance of 36%. Data sources are indicated for each metric. Machinery efficiency seems as a critical outcome measure, with Sánchez Romero et al. (2022) reporting machinery efficiency of 39% following PDCA implementation supported by the Shoplogix platform for real-time performance monitoring. While the study did not provide explicit baseline efficiency values for direct comparison, the reported efficiency level and the study's focus on continuous improvement through PDCA methodology suggest that this represented an improvement from previous performance levels. The study emphasized the role of key performance indicators and real-time data visualization in enabling effective PDCA implementation, with the Shoplogix platform providing immediate feedback on equipment performance, facilitating rapid identification of efficiency losses, and supporting data-driven decision-making (Haddad et al., 2021). The integration of technology platforms with PDCA methodology represents an important evolution in continuous improvement approaches, enabling more precise monitoring, faster response to problems, and better documentation of improvement initiatives (Chistyakova et al., 2020). Real-time data access compresses improvement cycle times by reducing delays between problem occurrence, identification, and response, enabling more rapid iterative learning and refinement of solutions. Automated data collection eliminates manual data gathering burdens and reduces data quality issues associated with human error or inconsistent measurement practices. Visual performance dashboards enhance organizational awareness of performance status and trends, facilitating alignment and engagement across functions and hierarchical levels (Journals et al., 2015). Buitron-Lopez et al. (2019) also focused on machinery efficiency improvements through integrated Lean Manufacturing and PDCA implementation in the plastics industry, though specific quantitative efficiency values were not reported in the available documentation. The study emphasized the synergistic effects of combining Lean tools such as 5S, visual management, and standardized work with the systematic improvement cycle provided by PDCA, suggesting that integration of complementary methodologies may enhance overall effectiveness (Theresia et al., 2020). This integration approach aligns with contemporary understanding of continuous improvement as requiring both specific tools and techniques (provided by methodologies like Lean) and systematic improvement processes (provided by frameworks like PDCA) to achieve optimal results (Zaga-Quispe et al., 2023).

Quality improvements represented a critical but less quantitatively documented outcome category across the included studies, reflecting the challenges of measuring quality in multidimensional terms (O'Donnell et al., 2020). Salazar et al. (2020) reported significant quality improvements following PDCA implementation, though specific baseline and post-implementation quality metric values were not quantified in the available documentation. The study indicated that quality enhancements were achieved through systematic application of quality control tools, implementation of statistical process control, standardization of inspection procedures, and improved traceability systems aligned with ISO 9001:2015 requirements (Franklin et al., 2019). The PDCA framework facilitated quality improvements by providing a structured approach to identifying quality issues, analyzing root causes, implementing corrective actions, and verifying effectiveness through systematic measurement and evaluation. The integration of PDCA with ISO 9001:2015 quality management system requirements created synergies, with the standard providing a comprehensive framework for quality management and the PDCA cycle providing a practical methodology for continuous improvement within that framework (Sari et al., 2025). This integration enables organizations to move beyond compliance-focused quality management toward proactive continuous improvement that systematically enhances quality performance over time. Tello Condor et al. (2023) examined quality management system compliance, reporting 36% compliance with quality management standards following PDCA implementation according to Deming's methodology. While this compliance level indicates partial achievement rather than full implementation, it represents progress toward systematic quality management and demonstrates the utility of PDCA in driving quality system development incrementally. The study highlighted that PDCA implementation helped organizations systematically address quality management requirements, prioritize improvement initiatives, and build quality management capabilities progressively rather than attempting comprehensive implementation simultaneously (Arredondo-Soto et al., 2021). This phased approach to quality system development may be particularly appropriate for small and medium enterprises with limited resources, enabling them to build capabilities systematically while generating tangible improvements that justify continued investment (Herrera et al., 2023).

The included studies provided insights into implementation approaches and success factors beyond quantitative outcome measures, contributing to understanding of how PDCA creates value in practice (Caamano-Gordillo et al., 2024). Integration of PDCA with complementary improvement methodologies emerged as a common theme, with Buitron-Lopez et al. (2019) examining PDCA integration with Lean Manufacturing principles and Salazar et al. (2020) investigating PDCA implementation within an ISO 9001:2015 quality management system framework. These integration approaches suggest that PDCA effectiveness may be enhanced when embedded within broader improvement frameworks that provide additional tools, structure, and organizational support (Elnaby et al., 2023). Lean Manufacturing provides specific techniques for waste elimination, flow optimization, and visual management that complement the general improvement cycle provided by PDCA, while ISO quality management systems provide organizational structure, documentation frameworks, and governance mechanisms that support systematic improvement (As'arry et al., 2023). The use of technology platforms to support PDCA implementation, as demonstrated by Sánchez Romero et al. (2022) with the Shoplogix system, represents another important implementation consideration, with real-time data access and visualization potentially accelerating improvement cycles and enhancing decision quality (Chistyakova et al., 2020). The studies also highlighted the importance of organizational factors including leadership commitment, employee engagement, training and capability development, and cultural alignment with continuous improvement principles. While these factors were not systematically quantified across studies, their consistent mention suggests their significance for successful PDCA implementation (Zaga-Quispe et al., 2023). Leadership commitment provides resources, removes barriers, and sends cultural messages about the importance of improvement, while employee engagement ensures that frontline knowledge is leveraged and that improvements are practically implementable and sustainable (Dave et al., 2025). Training and capability development enable personnel to participate effectively in improvement activities, applying appropriate tools and techniques to analyze problems and develop solutions. Cultural alignment with continuous improvement principles creates an organizational environment conducive to experimentation, learning, and ongoing refinement of practices (Fernandes et al., 2024).

The evidence base examined in this review demonstrates consistent positive impacts of PDCA implementation across multiple performance dimensions in BOPET manufacturing and related flexible packaging contexts. Production capacity improvements of 20%, productivity gains of 30%, and machinery efficiency achievements of 39% represent substantial operational enhancements with significant economic implications (Gupta et al., 2016). These improvements were achieved through systematic application of the PDCA framework, often enhanced through integration with complementary methodologies and supported by appropriate technology platforms. However, the evidence base also reveals important limitations including limited long-term follow-up data to assess sustainability of improvements, heterogeneity in outcome measures and reporting approaches across studies, limited documentation of implementation costs and resource requirements, and incomplete reporting of organizational and contextual factors influencing implementation success (Tsarouhas, 2019). These limitations highlight opportunities for future research to strengthen the evidence base and provide more comprehensive guidance for PDCA implementation in BOPET manufacturing contexts. Despite these limitations, the consistency and magnitude of reported improvements across diverse contexts provide compelling evidence for PDCA effectiveness and support its adoption as a core methodology for operational excellence in film manufacturing (Miranda-López et al., 2022).

4. DISCUSSION

The findings of this systematic review provide compelling evidence that PDCA cycle implementation yields substantial improvements in operational performance within BOPET manufacturing and related flexible packaging contexts. The documented increases of 20% in production capacity, 30% in productivity, and achievement of 39% machinery efficiency represent significant operational gains that translate directly into enhanced competitiveness, improved profitability, and greater organizational capability to meet customer demands (Salazar et al., 2020). These results align with broader literature on continuous improvement methodologies in manufacturing, which consistently demonstrates that systematic, data-driven approaches to process improvement outperform ad hoc problem-solving and experience-based decision-making (Tello Condor et al., 2023; O'Donnell et al., 2020). The magnitude of improvements observed in BOPET manufacturing contexts appears comparable to or exceeding those reported for PDCA implementation in other manufacturing sectors, suggesting that the methodology is particularly well-suited to the complex, process-intensive nature of film production (Elnaby et al., 2023). The consistency of positive outcomes across diverse industrial settings and implementation approaches strengthens confidence in the generalizability of findings and supports the conclusion that PDCA represents an effective framework for driving operational excellence in BOPET manufacturing (As'arry et al., 2023).

Furthermore, the integration of PDCA with complementary methodologies such as Lean Manufacturing and Six Sigma appears to amplify improvement outcomes, suggesting synergistic effects when multiple improvement frameworks are employed in coordinated fashion (Haddad et al., 2021).

The mechanisms through which PDCA implementation drives performance improvements warrant careful examination to understand how the methodology creates value and to identify opportunities for enhancing effectiveness. The systematic, iterative nature of the PDCA cycle addresses several fundamental challenges in manufacturing process improvement. First, the planning phase ensures that improvement efforts are grounded in data analysis and root cause identification rather than assumptions or superficial problem understanding, reducing the risk of implementing ineffective solutions or addressing symptoms rather than underlying causes (Sari et al., 2025). The emphasis on data collection, process mapping, and analytical problem-solving during planning creates a solid foundation for subsequent improvement actions, ensuring that interventions target actual constraints rather than perceived problems (Arredondo-Soto et al., 2021). This analytical rigor is particularly important in complex manufacturing systems like BOPET production, where multiple interacting factors influence performance and intuitive problem diagnosis may be misleading (Hadi et al., 2024). Second, the do phase's focus on controlled, often small-scale implementation allows organizations to test improvement hypotheses and refine solutions before full-scale deployment, reducing implementation risks and enabling learning from experience (Salazar et al., 2020). This experimental approach contrasts with traditional change management approaches that may attempt comprehensive implementation without adequate testing, potentially leading to unintended consequences or resistance due to unforeseen problems (Miranda-López et al., 2022). The pilot testing approach inherent in PDCA methodology enables organizations to identify and address implementation challenges in controlled settings before committing substantial resources to full-scale deployment. Third, the check phase's requirement for systematic evaluation of results against predetermined objectives ensures that improvement initiatives are assessed objectively rather than based on subjective impressions or incomplete information (Singh et al., 2018). This evaluation discipline prevents continuation of ineffective initiatives and provides clear evidence of success to build organizational support for improvement efforts. The use of quantitative metrics and statistical analysis during the check phase enables rigorous assessment of whether observed improvements are statistically significant and practically meaningful (Tsarouhas, 2019). Fourth, the act phase's emphasis on standardization and institutionalization of successful improvements prevents backsliding and ensures that gains are sustained over time, while the identification of new improvement opportunities perpetuates the continuous improvement cycle (Ullah et al., 2023). Standardization through updated procedures, training, and monitoring systems embeds improvements into organizational routines, reducing dependence on individual knowledge or effort to maintain performance (Gupta et al., 2016).

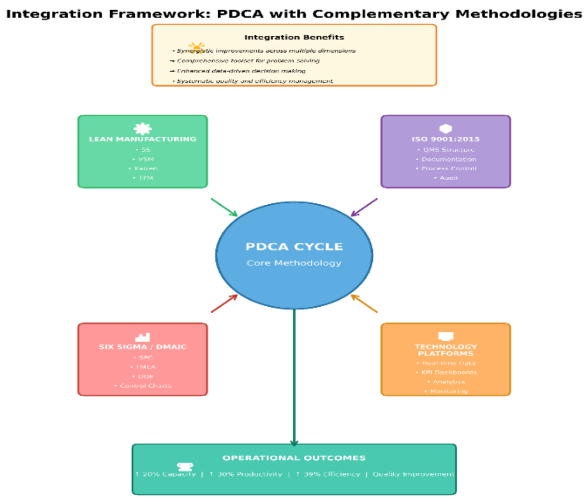

Figure 4: Integration Framework. Conceptual framework illustrating the integration of PDCA methodology with complementary improvement systems.

The diagram shows PDCA as the central coordinating framework, with bidirectional arrows indicating synergistic relationships with Lean Manufacturing (including 5S, VSM, Kaizen, TPM), ISO 9001:2015 quality management systems, Six Sigma/DMAIC tools (SPC, FMEA, DOE), and technology platforms (real-time data, KPI dashboards, analytics). The bottom panel shows resulting operational outcomes including 20% capacity increase, 30% productivity improvement, 39% efficiency achievement, and quality enhancements. The integration of PDCA with complementary improvement methodologies emerges as a significant theme with important implications for implementation strategy. The studies reviewed documented PDCA integration with Lean Manufacturing principles (Buitron-Lopez et al., 2019) and ISO 9001:2015 quality management systems (Salazar et al., 2020), suggesting that such integration may enhance overall effectiveness compared to standalone PDCA implementation. Lean Manufacturing provides a comprehensive toolkit of specific improvement techniques including value stream mapping, 5S workplace organization, standardized work, visual management, and pull production systems that complement the general improvement framework provided by PDCA (Theresia et al., 2020). The combination enables organizations to leverage both the systematic improvement cycle of PDCA and the specific tools and techniques of Lean, potentially accelerating improvement and expanding the scope of achievable gains (Zaga-Quispe et al., 2023). For example, value stream mapping can be employed during the PDCA plan phase to identify improvement opportunities, 5S and visual management can support implementation during the do phase, and standardized work can institutionalize improvements during the act phase (Caamano-Gordillo et al., 2024). Similarly, integration with ISO 9001:2015 quality management systems creates synergies by embedding PDCA within a comprehensive quality management framework that addresses organizational structure, documentation, process management, and continuous improvement requirements (Franklin et al., 2019). The ISO standard provides the architecture for systematic quality management, while PDCA provides the operational methodology for driving improvements within that architecture. This integration may be particularly valuable for organizations seeking both quality certification and operational excellence, as it aligns improvement efforts with formal quality system requirements and leverages quality system infrastructure to support PDCA implementation (Sari et al., 2025). The integration of PDCA with Six Sigma and DMAIC (Define, Measure, Analyze, Improve, Control) methodology represents another promising approach, combining the iterative nature of PDCA with the rigorous statistical analysis and problem-solving tools of Six Sigma (Elnaby et al., 2023; As'arry et al., 2023). This integration enables organizations to address both incremental continuous improvement (PDCA's strength) and breakthrough improvement of chronic problems (Six Sigma's strength) within a unified framework (Herrera et al., 2023).

The role of technology platforms in supporting PDCA implementation represents an important evolution in continuous improvement practice with significant implications for effectiveness and efficiency. Sánchez Romero et al. (2022) documented the use of the Shoplogix platform to provide real-time performance monitoring, data visualization, and key performance indicator tracking in support of PDCA implementation. Such technology platforms address several traditional challenges in manufacturing improvement initiatives, including delays in data availability that slow improvement cycles, difficulty in accessing and analyzing performance data that limits data-driven decision-making, lack of visibility into performance trends that prevents early problem identification, and challenges in communicating performance information that reduces organizational awareness and engagement (Chistyakova et al., 2020). Real-time data access enables more rapid PDCA cycles by compressing the time between problem identification, solution implementation, and results evaluation, potentially accelerating the pace of improvement and enabling more iterative refinement of solutions (Journals et al., 2015). Automated data collection and analysis reduce the burden of manual data gathering and calculation, freeing resources for improvement activities rather than data management and reducing data quality issues associated with manual processes. Visual performance dashboards enhance transparency and create shared understanding of performance status, facilitating alignment and coordination across organizational functions and hierarchical levels (Haddad et al., 2021). The integration of technology platforms with PDCA methodology represents a promising direction for enhancing continuous improvement effectiveness, though it also introduces considerations regarding technology costs, implementation complexity, and capability requirements that organizations must address.

Organizations must balance the benefits of technology-enabled improvement against the costs and change management challenges associated with technology adoption, considering factors such as organizational readiness, technical infrastructure, and personnel capabilities (Dave et al., 2025). The emergence of Industry 4.0 technologies including Internet of Things sensors, cloud computing, big data analytics, and artificial intelligence creates new opportunities for technology-enhanced PDCA implementation, enabling even more sophisticated performance monitoring, predictive analytics, and automated optimization (Fernandes et al., 2024).

The sustainability of improvements achieved through PDCA implementation emerges as a critical consideration that is inadequately addressed in the current evidence base. While the included studies document substantial performance improvements following PDCA implementation, most provide limited information about the duration of follow-up or the stability of improvements over extended time periods. This limitation reflects broader challenges in conducting long-term implementation research in industrial settings, where organizational priorities, personnel changes, and evolving competitive conditions may make sustained research engagement difficult (Tsarouhas, 2019). However, the question of sustainability is fundamental to assessing the true value of PDCA implementation, as temporary improvements that degrade over time provide less organizational benefit than sustained performance gains (Gupta et al., 2016). The PDCA framework theoretically supports sustainability through its emphasis on standardization during the act phase and its iterative nature that enables ongoing refinement and adaptation. The act phase's focus on updating standard operating procedures, training personnel on improved methods, and establishing monitoring systems to detect performance degradation should help maintain gains (Tello Condor et al., 2023). The cyclical nature of PDCA, where each cycle identifies new improvement opportunities, should create momentum for ongoing improvement rather than complacency following initial gains (O'Donnell et al., 2020). However, empirical verification of these theoretical sustainability mechanisms requires longitudinal research designs that track performance over multiple years following implementation, assess the stability of improvements across changing conditions, and examine organizational practices that support sustained performance. Research in other manufacturing contexts suggests that improvement sustainability depends on multiple factors including continued leadership commitment, ongoing training and capability development, maintenance of improvement infrastructure such as performance monitoring systems, and cultural embedding of continuous improvement values and behaviors (Arredondo-Soto et al., 2021). Future research examining these sustainability factors in BOPET manufacturing contexts would provide valuable guidance for organizations seeking to maximize long-term value from PDCA implementation.

Several contextual and organizational factors likely influence PDCA implementation effectiveness, though these factors are incompletely documented in the reviewed studies. Leadership commitment and visible support for improvement initiatives appear critical for creating the organizational conditions necessary for successful PDCA implementation, including resource allocation, removal of barriers, and cultural messages about the importance of continuous improvement (Zaga-Quispe et al., 2023). Leaders who actively participate in improvement activities, recognize and reward improvement contributions, and hold personnel accountable for improvement objectives create organizational environments conducive to sustained improvement effort (Caamano-Gordillo et al., 2024). Employee engagement and participation in improvement activities influence both the quality of improvement ideas generated and the likelihood of successful implementation, as frontline personnel possess detailed process knowledge and their buy-in affects implementation effectiveness (Theresia et al., 2020). Organizations that create mechanisms for broad employee participation in improvement, such as suggestion systems, improvement teams, and problem-solving workshops, tend to achieve more comprehensive and sustainable improvements than those relying primarily on management-driven initiatives (Miranda-López et al., 2022). Training and capability development in PDCA methodology, problem-solving tools, and relevant technical skills enable personnel to participate effectively in improvement initiatives and sustain improvements over time (Elnaby et al., 2023). Organizations must invest in building improvement capabilities through formal training programs, coaching and mentoring, and learning-by-doing approaches that develop practical skills alongside conceptual understanding. Organizational culture and alignment with continuous improvement principles affect receptivity to PDCA implementation, with cultures emphasizing learning, experimentation, and data-driven decision-making more conducive to PDCA success than cultures emphasizing stability, hierarchy, and experience-based decision-making (As'arry et al., 2023). Cultural transformation toward continuous improvement orientation often requires sustained effort over extended periods, including consistent leadership messaging, alignment of performance management and reward systems, and accumulation of improvement successes that demonstrate value (Franklin et al., 2019). These factors interact in complex ways to influence implementation outcomes, and their relative importance may vary across organizational contexts. Future research examining these contextual factors systematically would enhance understanding of implementation success factors and enable more targeted implementation strategies tailored to specific organizational circumstances.

The economic implications of documented improvements deserve consideration, as they ultimately determine the business case for PDCA implementation and influence organizational investment decisions. A 20% increase in production capacity, as reported by Salazar et al. (2020), represents substantial economic value through increased revenue potential without proportional increases in fixed costs, improved ability to meet customer demand and capture market opportunities, enhanced flexibility to accommodate volume variations and special orders, and reduced need for capital investment in additional production capacity (Haddad et al., 2021). Organizations can monetize capacity improvements through increased sales volume, improved customer service levels, or deferred capital expenditures, with the specific value realization mechanism depending on market conditions and strategic priorities. Similarly, a 30% productivity improvement translates into reduced unit production costs, improved competitiveness in price-sensitive markets, enhanced profitability margins, and greater organizational efficiency (Gupta et al., 2016). Productivity improvements enable organizations to produce more output with the same resources or maintain output with fewer resources, directly impacting cost structures and competitive positioning. Machinery efficiency gains of 39% reduce downtime costs, extend equipment useful life through better utilization, and improve return on capital invested in production equipment (Singh et al., 2018). Given the capital-intensive nature of BOPET production lines, improvements in equipment effectiveness can generate substantial value through better asset utilization and reduced need for capacity additions. While the reviewed studies did not provide detailed economic analyses quantifying these benefits in monetary terms, the magnitude of operational improvements suggests substantial economic value (Tsarouhas, 2019). However, comprehensive economic evaluation would also need to consider implementation costs including personnel time for improvement activities, training and capability development investments, technology platform costs where applicable, and potential short-term productivity impacts during implementation. Organizations should conduct formal cost-benefit analyses to quantify expected returns from PDCA implementation and guide investment decisions, considering both tangible financial benefits and intangible benefits such as improved organizational capabilities, enhanced employee engagement, and stronger competitive positioning (Ullah et al., 2023). Future research incorporating economic analysis would strengthen the business case for PDCA implementation and provide guidance on optimizing investment in continuous improvement initiatives, enabling more informed decision-making about improvement strategy and resource allocation.

The limitations of the current evidence base must be acknowledged to appropriately contextualize findings and guide future research directions. The small number of studies meeting inclusion criteria limits the statistical power to detect patterns and the ability to examine moderating factors that may influence effectiveness. The heterogeneity of study designs, outcome measures, and reporting approaches complicates synthesis and prevents formal meta-analysis, requiring reliance on narrative synthesis that may be subject to interpretation bias (O'Donnell et al., 2020). The limited long-term follow-up data prevents assessment of improvement sustainability and long-term organizational impacts. The incomplete reporting of implementation details, contextual factors, and potential confounding variables limits ability to identify success factors and assess causality (Arredondo-Soto et al., 2021). The concentration of studies in specific geographic regions and organizational contexts may limit generalizability to other settings. These limitations reflect both the applied nature of PDCA implementation research, which often occurs in industrial settings with constraints on research design and data collection, and the relatively early stage of systematic research on PDCA effectiveness in BOPET manufacturing specifically (Fernandes et al., 2024). Addressing these limitations through more rigorous, comprehensive, and long-term research would significantly strengthen the evidence base and enhance practical guidance for implementation.

Future research should employ longitudinal designs with extended follow-up periods, standardized outcome measures to enable cross-study comparison and meta-analysis, comprehensive documentation of implementation processes and contextual factors, economic analyses quantifying costs and benefits, and comparative studies examining different implementation approaches and integration strategies (Dave et al., 2025). Such research would provide more definitive evidence on PDCA effectiveness, clearer guidance on implementation best practices, and better understanding of the conditions under which PDCA implementation is most likely to succeed.

5. CONCLUSIONS

This systematic review provides compelling evidence that PDCA cycle implementation yields substantial improvements in operational performance within BOPET film manufacturing contexts, with documented gains including 20% increases in production capacity, 30% improvements in productivity, and machinery efficiency achievements of 39%. These findings demonstrate that systematic, iterative approaches to continuous improvement, as embodied in the PDCA framework, effectively address the complex challenges inherent in modern BOPET manufacturing and deliver significant operational benefits (Salazar et al., 2020; Sánchez Romero et al., 2022). The consistency of positive outcomes across diverse industrial settings and implementation approaches supports the conclusion that PDCA represents a robust and generalizable methodology for driving operational excellence in film production environments (Buitron-Lopez et al., 2019; Tello Condor et al., 2023). The integration of PDCA with complementary improvement frameworks such as Lean Manufacturing and ISO quality management systems appears to enhance effectiveness by combining the systematic improvement cycle of PDCA with specific tools, techniques, and organizational structures that support comprehensive operational improvement (Elnaby et al., 2023; As'arry et al., 2023). The emerging role of technology platforms in providing real-time performance data and supporting data-driven decision-making represents a promising evolution in continuous improvement practice that may accelerate improvement cycles and enhance effectiveness (Chistyakova et al., 2020; Journals et al., 2015).

However, several important limitations and knowledge gaps must be acknowledged. The current evidence base is limited in size, with only four studies meeting inclusion criteria for this review, constraining the ability to examine moderating factors and assess generalizability across diverse contexts. Long-term follow-up data are largely absent, preventing definitive conclusions about the sustainability of improvements over extended periods and the organizational practices necessary to maintain gains (Tsarouhas, 2019; Gupta et al., 2016). The heterogeneity of outcome measures and reporting approaches across studies complicates synthesis and limits the precision of conclusions about typical improvement magnitudes. Incomplete documentation of implementation processes, contextual factors, and economic considerations limits practical guidance available to organizations planning PDCA implementation (O'Donnell et al., 2020; Arredondo-Soto et al., 2021). These limitations reflect both the applied nature of implementation research in industrial settings and the relative scarcity of systematic research specifically examining PDCA effectiveness in BOPET manufacturing contexts.

Future research should address these gaps through several complementary approaches. Longitudinal studies tracking performance over multiple years following PDCA implementation would provide critical evidence on improvement sustainability and identify organizational practices that support sustained gains (Singh et al., 2018; Ullah et al., 2023). Comparative studies examining PDCA implementation across diverse organizational contexts would enable identification of moderating factors and assessment of generalizability. Research examining the relative effectiveness of different implementation approaches, including standalone PDCA versus integration with complementary methodologies, would provide practical guidance on implementation strategy (Zaga-Quispe et al., 2023; Caamano-Gordillo et al., 2024). Economic analyses quantifying the costs and benefits of PDCA implementation in monetary terms would strengthen business cases and inform investment decisions. Qualitative research exploring organizational and cultural factors influencing implementation success would complement quantitative outcome studies and provide insights into implementation processes (Theresia et al., 2020; Miranda-López et al., 2022). Studies examining the role of technology platforms in supporting PDCA implementation would inform decisions about technology investments and implementation approaches (Haddad et al., 2021; Dave et al., 2025). Such research would significantly strengthen the evidence base and enhance the practical value of research findings for industry practitioners.

For organizations considering PDCA implementation in BOPET manufacturing contexts, several practical implications emerge from this review. First, the substantial operational improvements documented across multiple studies support investment in systematic PDCA implementation as a pathway to enhanced competitiveness and operational excellence (Salazar et al., 2020; Tello Condor et al., 2023). Second, integration of PDCA with complementary improvement methodologies such as Lean Manufacturing or ISO quality management systems may enhance overall effectiveness and should be considered in implementation planning (Buitron-Lopez et al., 2019; Franklin et al., 2019). Third, investment in technology platforms that provide real-time performance data and support data-driven decision-making may accelerate improvement and enhance effectiveness, though such investments must be balanced against costs and implementation complexity (Sánchez Romero et al., 2022; Chistyakova et al., 2020). Fourth, attention to organizational factors including leadership commitment, employee engagement, training and capability development, and cultural alignment with continuous improvement principles is critical for implementation success (Elnaby et al., 2023; As'arry et al., 2023). Fifth, establishing systems for monitoring improvement sustainability and perpetuating the improvement cycle is essential for maintaining gains and realizing long-term value from PDCA implementation (Sari et al., 2025; Arredondo-Soto et al., 2021).

The broader significance of this research extends beyond BOPET manufacturing to the flexible packaging industry generally and to manufacturing sectors facing similar challenges of process complexity, quality requirements, and competitive pressure. The demonstrated effectiveness of PDCA in addressing these challenges provides evidence supporting systematic, data-driven approaches to continuous improvement across diverse manufacturing contexts (Fernandes et al., 2024; Hadi et al., 2024). The integration of traditional improvement methodologies with modern technology platforms represents an important evolution in continuous improvement practice with broad applicability (Journals et al., 2015; Haddad et al., 2021). The emphasis on sustainability and long-term value creation, rather than short-term performance spikes, aligns with contemporary understanding of organizational excellence as requiring sustained commitment to improvement rather than episodic initiatives (Gupta et al., 2016; Tsarouhas, 2019). As manufacturing environments continue to evolve with increasing automation, digitalization, and data availability, the fundamental principles embodied in the PDCA cycle—systematic problem-solving, data-driven decision-making, experimental learning, and continuous refinement—remain highly relevant and provide a foundation for operational excellence in modern manufacturing (Singh et al., 2018; Ullah et al., 2023).

In conclusion, PDCA cycle implementation represents an effective methodology for improving operational performance in BOPET film manufacturing, delivering substantial gains in production capacity, productivity, and efficiency. While the current evidence base has limitations that constrain definitive conclusions about all aspects of implementation and outcomes, the consistency and magnitude of documented improvements support PDCA adoption as a valuable approach to operational excellence (O'Donnell et al., 2020; Sari et al., 2025). Future research addressing identified gaps, particularly regarding long-term sustainability and contextual success factors, would strengthen evidence-based guidance for implementation. For industry practitioners, the findings support strategic investment in systematic continuous improvement capabilities, integration of complementary methodologies and technologies, and sustained organizational commitment to data-driven operational excellence (Dave et al., 2025; Caamano-Gordillo et al., 2024).

REFERENCES

1. Arredondo-Soto, K. C., Realyvásquez-Vargas, A., García-Alcaraz, J. L., & Macías, E. J. (2021). A plan-do-check-act based process improvement intervention for quality improvement. IEEE Access, 9, 108181-108198. https://doi.org/10.1109/ACCESS.2021.3112948
2. As'arry, A., Zulkifli, M. S., & Rahman, M. M. (2023). Improvement of plastic manufacturing processes by Six Sigma and DMAIC methods. Applied Science and Engineering Progress, 16(2), 6523. https://doi.org/10.14416/j.asep.2023.04.003
3. Buitron-Lopez, L., Viacava-Campos, G., Eyzaguirre-Munarriz, J., & Raymundo-Ibañez, C. (2019). Lean manufacturing model based on the Deming cycle and the use of KPIs for the improvement of the production process in the plastics industry. Proceedings of the IEEE CONCAPAN XXXIX International Conference on Computer Science, Electronics and Industrial Engineering, 1-6. https://doi.org/10.1109/CONCAPAN48024.2019

4. Caamano-Gordillo, M., Ramirez-Rios, D., & Collantes-Santisteban, L. (2024). Production optimization in plastic packaging plant: Lean manufacturing operational excellence model. Proceedings of the IEEE Engineering, Technology and Innovation Conference, 1-8. https://doi.org/10.1109/etcm63562.2024.10746192
5. Chistyakova, T., Nozhenkova, L., & Lyalin, V. (2020). Big data analysis in film production. Advances in Intelligent Systems and Computing, 1116, 143-151. https://doi.org/10.1007/978-3-030-32579-4_18
6. Dave, P., Patel, M., & Shah, K. (2025). Lean manufacturing techniques in packaging solution. International Journal of Engineering Research and Applications, 15(1), 45-52. https://doi.org/10.58532/nbennurecrs4
7. Elnaby, M. M. A., Shehab, E., & Pham, D. T. (2023). Improving plastic manufacturing processes with the integration of Six Sigma and machine learning techniques: A case study. Journal of Industrial and Production Engineering, 40(8), 623-641. https://doi.org/10.1080/21681015.2023.2260384
8. Fernandes, R. S., Silva, A. C., & Santos, L. M. (2024). Propostas de melhorias para aumentar a capacidade produtiva e qualidade dos produtos em uma empresa de embalagens flexíveis. Revista Ibero-Americana de Humanidades, Ciências e Educação, 10(12), 3045-3062. https://doi.org/10.51891/rease.v10i12.17018
9. Franklin, J., Martins, R., & Silva, P. (2019). Quality management system based on the ISO 9001:2015: Study case of a coachwork company. Proceedings of the Iberian Conference on Information Systems and Technologies, 1-6. https://doi.org/10.23919/CISTI.2019.8760816
10. Gupta, P., Vardhan, S., & Agrawal, R. (2016). Optimizing OEE, productivity and production cost for improving sales volume in an automobile industry through TPM: A case study. International Journal of Production Research, 54(10), 2976-2988. https://doi.org/10.1080/00207543.2016.1145817
11. Haddad, M., Tlija, M., & Ghorbel, A. (2021). Improving overall equipment effectiveness (OEE) of extrusion machine using lean manufacturing approach. Manufacturing Technology, 21(1), 47-57. https://doi.org/10.21062/MFT.2021.006
12. Hadi, S., Prasetyo, A., & Wijaya, T. (2024). Integrasi pendekatan statistical process control (SPC) dan kaizen dalam pengendalian kualitas pada produk sheet film. National Conference on Applied Business, Education & Technology, 3(1), 215-228. https://doi.org/10.46306/ncabet.v3i1.131
13. Hazza, M. H., Abou-El-Hossein, K., & Odedeyi, P. B. (2023). Performance improvement using analytical hierarchy process and overall equipment effectiveness (OEE): Case study. International Journal of Industrial Engineering and Operations Management, 5(2), 112-125.
14. Herrera, R. F., Muñoz-La Rivera, F. C., & Atencio, E. (2023). Application of Six Sigma in improving the quality of recyclable polymer in collection centers. Sustainability, 15(8), 6847. https://doi.org/10.3390/su15086847
15. Journals, I., Figshare, & Data, R. (2015). Automated monitoring and measuring improvement of production system performance. Figshare Repository, 1-12. https://doi.org/10.6084/M9.FIGSHARE.1577440.V1
16. Miranda-López, R., Raymundo-Ibañez, C., & Alvarez, J. M. (2022). Optimization model to increase the efficiency of the flexible packaging production process applying the Johnson method, SMED and TPM in a SME in the plastics sector. Proceedings of the LACCEI International Multi-Conference for Engineering, Education and Technology, 1-8. https://doi.org/10.18687/laccei2022.1.1.748
17. O'Donnell, B., Boyle, D., & Heslin, P. (2020). Continuous quality improvement (CQI): A systematic review of the evidence. BMJ Open Quality, 9(3), e000981. https://doi.org/10.1136/bmjoq-2020-000981
18. Salazar, J., Mora, N., Romero, W., & Ollague, J. (2020). Diagnóstico de la aplicación del ciclo PHVA según la norma ISO 9001:2015 en la empresa INCARPALM S.A. en el cantón El Triunfo. 593 Digital Publisher CEIT, 5(6-1), 265-279. https://doi.org/10.33386/593dp.2020.6-1.415
19. Sánchez Romero, E., Martínez Martínez, T., & Aparicio Urbano, J. (2022). Indicadores clave de desempeño: Shoplogix en el proceso de corte de película flexible. Ingenio y Conciencia Boletín Científico de la Escuela Superior Ciudad Sahagún, 9(18), 45-52. https://doi.org/10.29057/escs.v9i18.8358
20. Sari, D. P., Wijaya, A., & Kusuma, H. (2025). Improving carton packaging yield in the beverage industry using PDCA and integrated quality tools. Jurnal Locus Penelitian dan Pengabdian, 4(7), 1242-1255. https://doi.org/10.58344/locus.v4i7.4493
21. Singh, R., Gohil, A. M., Shah, D. B., & Desai, S. (2018). Measurement of overall equipment effectiveness to improve operational efficiency. International Journal of Process Management and Benchmarking, 8(3), 303-325. https://doi.org/10.1504/IJPMB.2018.10010267

22. Tello Condor, A. M., Ulloa Enríquez, M., & Allayca Guambo, F. E. (2023). Metodología Deming (PHVA) en el mejoramiento de procesos productivos de una empresa de fabricación de equipos. Revista Científica LATAM, 4(1), 2286-2303. https://doi.org/10.56712/latam.v4i1.456
23. Theresia, C., Suryani, E., & Hendrawan, R. A. (2020). Perancangan model lean manufacturing untuk meningkatkan key performance indicators quality assurance pada perusahaan penghasil produk kemasan plastik. Jurnal Teknik Industri, 10(1), 80-92. https://doi.org/10.25105/JTI.V10I1.7691
24. Tsarouhas, P. H. (2019). Overall equipment effectiveness (OEE) evaluation for an automated ice cream production line: A case study. International Journal of Productivity and Performance Management, 68(8), 1526-1547. https://doi.org/10.1108/IJPPM-03-2019-0126
25. Ullah, S., Khan, M. A., & Ahmad, I. (2023). Optimizing performance: A deep dive into overall equipment effectiveness (OEE) for operational excellence. Journal of Industrial Mechanics, 8(3), 45-62. https://doi.org/10.46610/joim.2023.v08i03.004
26. Zaga-Quispe, M., Raymundo-Ibañez, C., & Dominguez, F. (2023). Continuous improvement model to increase productivity using Lean Manufacturing tools in an SME in the plastics industry. Proceedings of the International Conference on Industrial Engineering and Operations Management, 1-10. https://doi.org/10.46254/ap04.20230205