Terbit *online* pada laman : http://teknosi.fti.unand.ac.id/

Jurnal Nasional Teknologi dan Sistem Informasi

| ISSN (Print) 2460-3465 | ISSN (Online) 2476-8812 |

Stusi Kasus

Integrating Good Manufacturing Practices, Lean Manufacturing, and Information Technology for Operational Excellence in Indonesian Food SMEs

Ahmad Syafruddin Indrapriyatna [a,*], *Reinny Patrisina* [a], *Asi Siva Dea* [b], *Nahda Sulasi* [b], *Yonithri Sherlyna* [b]

[a] *Departemen Teknik Industri Universitas Andalas, Kampus Limau Manis, Padang 25164, Indonesia*
[b] *Departemen Teknik Industri Universitas Andalas, Kampus Limau Manis, Padang 25164, Indonesia*

INFORMASI ARTIKEL

Sejarah Artikel:
Diterima Redaksi: 12 November 2025
Revisi Akhir: 08 Desember 2025
Diterbitkan *Online*: 28 Desember 2025

KATA KUNCI

Good Manufacturing Practices,
Lean Manufacturing,
Teknologi Informasi,
Process Cycle Efficiency,
Industri Kecil Menengah

KORESPONDENSI

E-mail: ahmadsi@eng.unand.ac.id*

A B S T R A C T

Meskipun industri pangan skala kecil dan menengah menghadapi berbagai tantangan signifikan, terdapat potensi yang menjanjikan untuk peningkatan. Industri-industri ini, yang berperan penting dalam pembangunan ekonomi daerah, dapat mengatasi permasalahan terkait kebersihan, ketidakefisienan, dan pemborosan dalam proses produksinya. Penelitian ini, yang didasarkan pada tiga studi kasus yaitu IKM Kerupuk Janek Arsyila, IKM Kerupuk Buk Ita, dan UMKM Kue Bawang Medan "Rizka" di Sumatera Barat, mengidentifikasi isu-isu utama seperti tata letak yang tidak efisien, ketergantungan terhadap cuaca, ketiadaan prosedur standar, serta rendahnya kepatuhan terhadap standar kebersihan. Penelitian ini mengintegrasikan *Good Manufacturing Practices* (GMP) untuk evaluasi kebersihan dan berbagai alat *Lean Manufacturing* digunakan untuk mengidentifikasi serta mengurangi pemborosan. Selain itu, Teknologi Informasi (TI) diperkenalkan sebagai pendukung untuk memperkuat kegiatan pemantauan, pengumpulan data, dan pendokumentasian. Studi ini menekankan peran alat digital sederhana seperti *production dashboard*, daftar pemeriksaan kebersihan berbasis ponsel, dan sensor berbantuan IoT dalam memfasilitasi pengawasan secara waktu nyata (*real-time*) serta meningkatkan kepatuhan terhadap GMP. Hasil penelitian menunjukkan bahwa jenis pemborosan yang paling dominan meliputi transportasi, gerakan (*motion*), cacat produk (*defect*), dan waktu menunggu (*waiting*), dengan *Process Cycle Efficiency* (PCE) awal berkisar antara 41% hingga 65%. Setelah dilakukan perbaikan berupa redesain tata letak, penggunaan mesin pengering, pencatatan digital, serta penerapan prinsip 5S, nilai PCE meningkat menjadi 81%–95%. Penelitian ini membuktikan bahwa integrasi antara Lean–GMP dan alat digital, disertai penerapan praktis prinsip 5S, dapat secara signifikan meningkatkan efisiensi produksi, standar kebersihan, dan keberlanjutan pada industri pangan kecil dan menengah di Indonesia.

1. INTRODUCTION

Micro, small, and medium enterprises (MSMEs) play a crucial role in sustaining economic growth and supporting the food supply chain in developing countries. In Indonesia, the food and beverage industry remains one of the most significant contributors to the national economy, recording a 5.82% year-on-year growth in the third quarter of 2024 [1]. Food MSMEs, typically characterized by limited capital, simple production systems, and small-scale labor, serve as key drivers of employment, innovation, and local economic resilience [2], [3].

Despite their strategic importance, food-processing MSMEs often face persistent operational challenges related to production efficiency, hygiene, and quality control. Common issues include dependency on manual and weather-sensitive processes, inefficient facility layouts, and a lack of standardized sanitation and safety practices. These factors contribute to multiple forms of production waste—such as waiting, transportation, overprocessing, defect, and motion—which reduce productivity and increase operational costs [4], [5].

Three representative MSMEs from West Sumatra exemplify these issues. The first enterprise, a small-scale producer of animal-based crackers, experiences up to 46% waste during the

https://doi.org/10.25077/TEKNOSI.v11i3.2025.235-243

drying and soaking stages, as well as transportation waste resulting from inefficient material flow and workspace arrangement. The second enterprise, a cassava-based snack producer, struggles with defective waste resulting from traditional sun-drying methods and overprocessing due to repeated manual molding, which together lead to high product losses during rainy seasons. The third enterprise, a home-based fried-snack manufacturer, faces hygiene risks associated with manual handling, frequent product breakage (resulting in defective waste), and motion waste due to unoptimized workstation layouts.

These cases reflect broader systemic issues affecting Indonesian food MSMEs: limited technology adoption, reliance on non-standardized manual practices, and vulnerability to environmental factors that reduce production consistency and quality. Addressing these inefficiencies requires a structured improvement approach such as lean manufacturing, which emphasizes the elimination of non-value-added activities and the continuous enhancement of process flow. Prior studies have shown that lean tools—such as 5S, value stream mapping (VSM), and just-in-time (JIT)—significantly improve process efficiency and waste reduction in small food industries [2], [3], [4]. The integration of lean manufacturing with total quality management (TQM) principles has also been found to strengthen sustainability performance across economic, social, and environmental dimensions [6]. However, empirical evidence on how these approaches are applied in micro- and small-scale food enterprises, particularly in developing-country contexts, remains limited.

Lean manufacturing, a systematic approach that aims to identify and eliminate non-value-added activities (waste) through continuous improvement, has its roots in the Toyota Production System (TPS). It emphasizes principles such as just-in-time (JIT), jidoka (automation with a human touch), heijunka (production leveling), and kaizen (continuous improvement). The primary objective of lean manufacturing is to maximize customer value by delivering high-quality products at reduced cost and shorter lead times [7]. Recent studies confirm that integrating lean with Industry 4.0 technologies not only enhances process flexibility and waste elimination but also provides firms with a more decisive competitive advantage, painting an optimistic picture of the future of manufacturing [8][9].

Waste (muda) refers to activities that consume resources but do not create value from the customer's perspective. Traditionally, seven categories of waste are identified: overproduction, waiting, transportation, inventory, motion, overprocessing, and defects. A later extension includes the eighth waste, non-utilized talent, summarized by the acronym DOWNTIME [10]. Effective waste elimination requires differentiating between value-added activities (VA), non-value-added (NVA), and necessary but non-value-added activities (NNVA). Recent findings suggest that prioritizing waste through structured frameworks, such as the Waste Relationship Matrix, can substantially increase productivity [11].

Value Stream Mapping (VSM), one of the most widely adopted lean tools, offers a visual representation of material and information flows from suppliers to customers. It distinguishes between value-added and non-value-added activities, thereby helping organizations identify bottlenecks and opportunities for improvement. This visualization is crucial for understanding the current state of the process and projecting the desired lean system after improvements have been implemented. In the digital era, VSM has been extended to incorporate simulation and big data analytics, enabling the optimization of decision-making and the prediction of improvement outcomes [12], [13].

Beyond VSM, lean provides several analytical tools for waste identification, including the Waste Relationship Matrix (WRM), Waste Assessment Questionnaire (WAQ), and Value Stream Analysis Tools (VALSAT), which comprise Process Activity Mapping, Supply Chain Response Matrix, Quality Filter Mapping, and Demand Amplification Mapping. Recent research has demonstrated that combining WRM, WAQ, and VALSAT enhances the accuracy of waste diagnosis and supports targeted improvement strategies [12]. Beyond these analytical frameworks, the use of Information Technology offers new opportunities to support lean–GMP implementation.

While lean focuses on efficiency, the food and pharmaceutical industries also require compliance with Good Manufacturing Practice (GMP) and Hazard Analysis and Critical Control Point (HACCP) to ensure product quality and safety. GMP sets fundamental standards on hygiene, sanitation, and documentation, while HACCP identifies and controls critical points to prevent contamination risks. The integration of lean with GMP/HACCP not only enhances operational performance but also instills consumer trust, reassuring the audience about the high standards in these industries [14].

Continuous improvement (Kaizen) and workplace organization, achieved through the 5S principles (Seiri, Seiton, Seiso, Seiketsu, Shitsuke), are essential for sustaining a lean culture across all organizational levels. Additionally, the Fishbone Diagram (also known as the Ishikawa Diagram) remains a valuable tool for root cause analysis, enabling the identification of underlying factors contributing to inefficiency and defects [15].

The integration of Information Technology (IT) has become an essential enabler for the successful implementation of Lean–GMP systems, particularly in small and medium enterprises (SMEs). Lean-GMP systems refer to a combination of Lean manufacturing principles, which focus on reducing waste and improving efficiency, and Good Manufacturing Practice (GMP), which ensures that products are consistently produced and controlled according to quality standards. IT allows firms to digitalize their operations, enhance data visibility, and strengthen decision-making processes through real-time monitoring and analytics. According to [16]Digitalization enables SMEs to overcome typical barriers to Lean adoption by improving communication, resource allocation, and waste identification.

For food manufacturing SMEs, the application of low-cost digital tools, such as barcode tracking, cloud-based documentation, and mobile checklists, is a game-changer. These tools significantly enhance traceability and hygiene compliance, key components of Good Manufacturing Practice (GMP). By reducing manual errors and providing continuous feedback loops, these digital applications not only enhance quality control but also boost operational efficiency [17].

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[18] further emphasizes that digital transformation serves as the bridge connecting traditional operations with the Industry 4.0 environment. It facilitates predictive decision-making by linking machine performance data to Lean indicators. [19] also highlights that even micro-enterprises can benefit from adopting basic digital platforms for inventory management and customer tracking. These findings confirm that Information Technology is not just a tool, but a transformative force that supports Lean–GMP integration, creating a data-driven, continuous improvement ecosystem.

Prior research consistently shows that lean implementation across manufacturing and service industries significantly improves productivity, reduces lead times, and lowers defect rates. More recent studies have highlighted the synergy between lean practices and digital technologies, such as IoT, big data, and AI, which enable real-time monitoring and predictive waste reduction [12].

2. METHOD

This research aims to pioneer a novel improvement model that integrates Lean Manufacturing and Good Manufacturing Practice (GMP) to enhance hygiene and production efficiency in small-scale food industries. The methodological flow encompasses a preliminary study, literature review, problem formulation, method selection, data collection, processing, analysis, and drawing of conclusions.

The study began with field visits and structured interviews at three SMEs producing traditional snacks: cow-skin crackers (Arsyila), cassava crackers (Buk Ita), and onion cookies (Rizka). Observations focused on workflows, equipment, and hygiene practices. The findings revealed several problems, including poor sanitation and multiple forms of production waste, such as waiting, motion, transportation, defects, and redundant processing. These inefficiencies significantly reduced both productivity and product quality.

The literature review provided theoretical grounding from Lean Manufacturing and GMP. Lean Manufacturing emphasizes waste elimination and value creation, whereas GMP ensures product safety through adherence to hygiene standards. Key analytical frameworks, including Value Stream Mapping (VSM), Waste Assessment Model (WAM), Value Stream Analysis Tools (VALSAT), Fishbone Diagram, and 5S methodology, were employed to identify waste sources, determine root causes, and establish effective workplace improvement practices.

The combined insights from field observation and literature review led to three central issues: hygiene non-compliance with GMP standards, production inefficiencies, and suboptimal layout arrangements. The study thus sought to determine the types and causes of waste and propose improvements to increase hygiene, efficiency, and product quality.

The research employed an integrated Lean–GMP approach. The researchers applied Lean Manufacturing methods to analyze process flows and eliminate non-value-added activities. They used GMP guidelines to evaluate hygiene practices related to sanitation, worker behavior, and equipment cleaning. The Waste Assessment Model (WAM) was used to identify and prioritize waste through two instruments: the Waste Relationship Matrix (WRM) and Waste Assessment Questionnaire (WAQ). The combined scores informed the VALSAT analysis, which was used for a detailed examination of waste. We identified root causes using the Fishbone Diagram and proposed layout and workplace improvements based on 5S principles. Hygiene evaluation was conducted through observation, interviews, and GMP-based checklists.

Primary data was collected through direct observations of production processes, time studies, and interviews with owners and workers. Questionnaires were used to assess waste relationships and frequency of occurrence. Secondary data, such as production records and layout documents, supported the analysis. All data were processed systematically through hygiene assessment, data consistency checks, and visualization using Current State Mapping. Waste identification and weighting results were validated through triangulation of qualitative and quantitative findings. The analysis then applied VALSAT to identify critical waste sources, followed by Fishbone and 5S-based improvement designs. A Future State Mapping illustrated the optimized production process.

A comparative analysis was performed between current and improved conditions to measure performance gains. Indicators such as lead time, cycle time, and Process Cycle Efficiency (PCE) were used to evaluate the impact of integrating Lean and GMP. The proposed model successfully reduced waste, enhanced hygiene compliance, and increased productivity across the participating SMEs, providing a reassuring validation of our research.

In conclusion, the integration of Lean Manufacturing and GMP has led to tangible improvements in hygiene and operational performance. This approach has proven to be effective in optimizing production systems in small-scale food enterprises. The findings suggest that the Lean–GMP integration can serve as a practical framework for other food industries grappling with similar challenges. We encourage further studies to apply this model to a broader range of SMEs and quantitatively assess the relationship between hygiene improvement and efficiency gains.

3. RESULTS

3.1. Overview of Production Processes

The observations and interviews conducted at the three small-scale food enterprises—Arsyila (cow-skin crackers), Buk Ita (cassava crackers), and Rizka (onion cookies)—revealed that all businesses rely heavily on manual labor and traditional processing methods. While each enterprise has distinct raw materials and production characteristics, the similar workflow patterns and operational constraints observed suggest a common potential for improvement.

At Arsyila, production involves boiling, drying, slicing, and seasoning cow-skin materials before packaging. The workflow is largely linear but inefficient due to long walking distances and overlapping movements between preparation and drying areas.

Only limited mechanical tools are used, and most activities depend on manual handling. The total production cycle time averaged 147,600 seconds, with only 54% of the time classified as value-added activities.

At Buk Ita, the cassava cracker production process consists of nine steps: peeling, washing, steaming, slicing, mixing, grinding, flattening, molding, and drying. The process remains fully manual, with a heavy reliance on knives, wooden presses, and sun drying. Despite consistent worker experience, inefficiencies were found in motion, repetitive activities, and material transportation. Overall, these observations confirm that the three enterprises share structural limitations typical of micro-scale production, including a lack of mechanization, dependence on environmental conditions, and low process standardization. This shared experience underscores the need for collective solutions and industry-wide improvements.

3.2. Waste Patterns and Efficiency Results

The Waste Assessment Model (WAM) is a comprehensive tool that includes the Waste Relationship Matrix (WRM) and Waste Assessment Questionnaire (WAQ). The WRM helps identify the relationship between different types of waste, while the WAQ is a structured survey that collects data on waste generation and management. By applying the WAM to the three enterprises, we were able to identify the dominant forms of waste and their impact on productivity.

For Arsyila, the top three wastes were transportation (20.5%), inventory (16.4%), and waiting (14.5%). Transportation waste resulted from poor layout planning and the absence of material-handling tools, forcing workers to move raw and semi-finished materials manually between distant workstations. Inventory waste occurred because raw materials were stored in large quantities without accurate demand forecasting, resulting in inefficient space utilization and occasional spoilage. Waiting waste was primarily due to weather-dependent drying and inadequate supervision schedules.

In Buk Ita, four wastes were highly significant: defect (23.7%), motion (17.8%), waiting (16.4%), and transportation (13.1%). The defect waste stemmed from non-uniform drying and breakage of crackers during sun exposure, particularly during cloudy days. Motion waste arose from unnecessary worker movements between slicing, mixing, and drying areas, while waiting waste was caused by downtime during cleaning or sun-drying.

Rizka displayed a similar trend, with defect (19.6%), motion (18.2%), and process waste (14.8%) as dominant types. Defects occurred due to inconsistent dough thickness and manual cutting errors. Motion waste was associated with the repetitive handling of trays and manual frying, while process waste stemmed from the redundant remixing of leftover dough.

Comparative analysis revealed that manual operations and unbalanced workflows were everyday across all enterprises. The overall Process Cycle Efficiency (PCE) values, which indicate the proportion of total production time that creates value, were 54% for Arsyila, 57.95% for Buk Ita, and 64.76% for Rizka. These values indicate that a substantial portion of production time is spent on non-value-added activities. However, after implementing layout redesigns, use of small-scale tools, and minor mechanization, PCE values improved significantly, reaching over 80% in all cases, with Buk Ita achieving the highest post-improvement PCE of 91.88%.

3.3. Hygiene and Sanitation Findings

The GMP-based hygiene assessment is a systematic evaluation that measures compliance with Good Manufacturing Practices (GMP) in food production. It covers areas such as sanitation, worker hygiene, and the cleanliness of infrastructure. At Arsyila, the assessment revealed a hygiene score of 66.84%, which falls into the "requires improvement" category. While labeling and packaging areas were adequately managed, issues persisted in sanitation, worker hygiene, and the cleanliness of infrastructure. Workers often neglected the use of protective equipment, and cross-contamination risk was observed between raw and processed material zones.

Buk Ita displayed moderate hygiene performance. The main issues were linked to limited waste disposal facilities, unsealed drying areas exposed to dust, and a lack of systematic equipment cleaning schedules. However, workers demonstrated a reasonable awareness of personal cleanliness, washing their hands regularly, and maintaining clean uniforms.

At Rizka, hygiene performance was slightly higher, supported by a smaller production scale and better air circulation. However, survey results revealed low compliance with certain hygiene practices: only 36% of workers used head covers, 18% wore gloves, and none used masks during processing. Environmental sanitation met 80% of the GMP criteria; however, inadequate ventilation and inconsistent cleaning frequency remained significant challenges.

These results show that hygiene management across the three SMEs largely depends on owner supervision and individual discipline rather than formal SOPs. Integrating GMP standards through routine hygiene checks, training, and visual reminders could significantly improve compliance.

3.4. Reliability and Integration of Findings

Multiple data sources support the results presented to ensure reliability and validity. Time measurements were taken repeatedly under different production conditions to capture fluctuations caused by weather and worker pace. Questionnaire responses were validated through interviews with both workers and owners to cross-check consistency. Statistical uniformity and adequacy tests confirmed that the number of samples and observations met the 95% confidence threshold, indicating reliable data representation.

Qualitative and quantitative findings were integrated to create a holistic interpretation. For example, high transportation waste percentages were supported by direct observation of long walking distances and poorly arranged workstations. Similarly, the correlation between low hygiene scores and defect rates emphasized how inadequate sanitation can directly affect product quality. Integrating WRM, WAQ, and GMP evaluations allowed triangulation between numerical data (efficiency metrics) and behavioral patterns (worker routines and discipline).

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This mixed-method integration strengthens the credibility of findings. It demonstrates that productivity and hygiene problems in micro food industries are not isolated technical issues but interconnected systems shaped by both process design and human behavior.

3.5. Summary of Key Outcomes

The overall results indicate that integrating Lean Manufacturing and GMP principles provided measurable benefits for all three enterprises. Waste reduction was achieved primarily through layout reorganization, basic mechanization, and clearer division of work responsibilities. Transportation and motion waste declined by over 40% on average, while overall cycle times were shortened by 30–50%, depending on the production scale.

From a financial perspective, the proposed interventions were highly feasible. Arsyila's total investment of approximately IDR 46.8 million achieved a payback period of one month. In contrast, Buk Ita's IDR 63.9 million investment achieved a 2.7-month payback with a positive Net Present Worth (NPW) exceeding IDR 825 million. Rizka's low-cost improvements (around IDR 14.8 million) yielded immediate operational benefits without significant capital risk.

The results also highlight the dual benefits of Lean-GMP implementation: productivity gains and improvements in hygiene. Enhancing layout and process flow indirectly improved cleanliness by reducing clutter and simplifying cleaning routines. Similarly, applying 5S and standard operating procedures (SOPs) improved both time efficiency and product safety.

In summary, the results confirm that even small, incremental interventions—when systematically designed using Lean and GMP frameworks—can yield significant improvements in efficiency, quality, and sustainability. The combination of process restructuring, training, and low-cost mechanization provides a practical model for small-scale food enterprises to achieve measurable industrial upgrading within limited resources.

The findings presented in this section provide a comprehensive overview of production conditions, waste characteristics, hygiene performance, and efficiency outcomes across the three studied enterprises. While the results quantify the extent of inefficiencies and hygiene gaps, they also highlight the underlying behavioral and managerial issues that shape operational performance. These interlinked dimensions of process design, worker discipline, and technology adoption form the basis for a more in-depth discussion in the subsequent sections.

The following section elaborates on how the integration of Lean Manufacturing and Good Manufacturing Practice (GMP) principles addresses these challenges, interprets the observed improvements, and explains their broader implications for small-scale food manufacturing. The discussion further connects these empirical findings with theoretical frameworks and practical strategies to demonstrate the replicability and sustainability of Lean-GMP implementation in similar industrial contexts.

4. DISCUSSION

The results presented in the previous section revealed significant improvements in process performance, efficiency, and hygiene across the three analyzed enterprises—Arsyila, Buk Ita, and Rizka—following the application of Lean Manufacturing and Good Manufacturing Practice (GMP) principles. However, numerical improvements alone do not fully capture the practical and theoretical significance of these findings. This discussion, therefore, interprets the mechanisms behind those improvements, linking the quantitative results to the behavioral, managerial, and technical transformations that occurred within each enterprise.

Beyond examining individual outcomes, this section compares the results across cases, highlights the interdependence between waste reduction and hygiene management, and elaborates on the proposed process improvements. It also situates the findings within broader industrial and sustainability perspectives, demonstrating how the Lean-GMP integration model can enhance productivity, quality, and resilience in small-scale food manufacturing systems.

4.1. Interpretation of Process and Efficiency Improvements

The implementation of Lean Manufacturing and Good Manufacturing Practice (GMP) principles in the three observed enterprises—Arsyila, Buk Ita, and Rizka—produced significant improvements in process performance, efficiency, and hygiene compliance. The findings in Chapter 4 indicate that all three enterprises initially suffered from unbalanced workflows, long transportation distances, manual handling, and irregular sanitation practices. These inefficiencies were compounded by a lack of standard operating procedures (SOPs) and an overreliance on human labor.

After the integration of Lean-GMP concepts, each enterprise exhibited measurable improvements in process efficiency. For Arsyila, the Process Cycle Efficiency (PCE) rose dramatically from 41.82% to 95.24%, mainly due to the introduction of a linear material flow and small-scale mechanization. Buk Ita's PCE improved from 57.95% to 91.88%, while Rizka's increased from 64.76% to 81.60%, illustrating that systematic waste reduction and process discipline can deliver quantifiable results even in micro-scale industries.

The improvement in PCE values was not only technical but also behavioral. Workers displayed greater consistency in task execution after layout streamlining and clearer work division. The visual control inherent in 5S practices (Seiri, Seiton, Seiso, Seiketsu, and Shitsuke) improved overall coordination and accountability. Additionally, the introduction of one-way flow layouts minimized cross-traffic between workers and reduced fatigue from unnecessary motion. These operational refinements confirmed that Lean methods, when tailored to small-scale contexts, effectively eliminate non-value-added activities and build a foundation for continuous improvement.

Although the improvements varied across enterprises, the underlying mechanisms were consistent. The transition from disorderly, manual workflows to structured and semi-automated processes resulted in shorter cycle times, lower product defects, and increased worker awareness. These outcomes reflect the synergistic relationship between efficiency and quality: the more streamlined the process, the more consistent and hygienic the output becomes.

4.2. Waste, Hygiene, and Proposed Improvements

The analysis of waste and hygiene results across the three enterprises revealed recurring inefficiencies and sanitation gaps. Transportation, motion, waiting, and defect wastes were the most prevalent issues, while hygiene problems primarily stemmed from poor zoning, insufficient cleaning, and limited use of personal protective equipment. The proposed improvements, therefore, combined process streamlining with hygiene reinforcement through layout redesign, low-cost mechanization, and enforcement of GMP standards specific to each case.

Arsyila (Cow-Skin Crackers)
At Arsyila, transportation waste (20.5%), inventory waste (16.4%), and waiting waste (14.5%) were identified as the primary sources of inefficiency. Long material movement and a lack of handling tools forced workers to repeatedly move raw cow-skin materials across the workspace, creating delays and contamination risks. The proposed linear layout reorganized the production flow sequentially from peeling to washing, coating, and drying, with separate storage areas for raw and finished products to maintain one-way movement (see Figure 1).

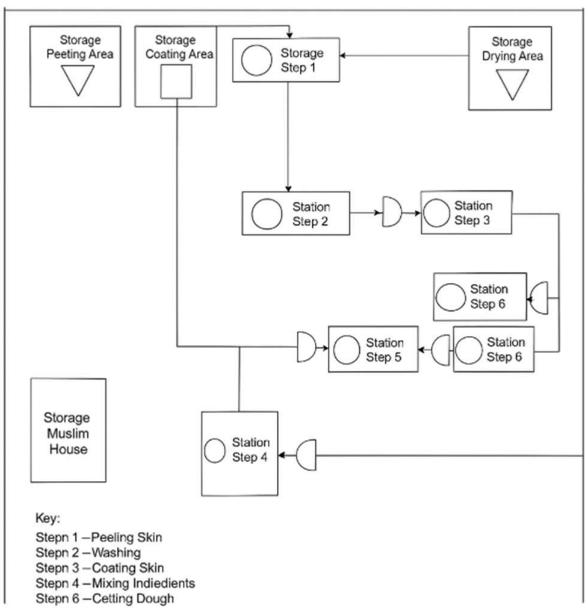

Figure 1. Proposed Layout for Arsyila

To address bottlenecks, two tools were introduced: a tray dryer (Figure 2) to replace sun drying and a Zeppelin spinner (Figure 3)to accelerate oil drainage. These machines reduced total drying time by 35%, reducing waste by 40%, and improved hygiene by eliminating exposure to external contaminants. The restructured layout reduced transportation distance by 32% and increased PCE to 95.24%, transforming Arsyila's process from fragmented to fully streamlined.

Figure 2. Proposed Try Dryers Machine

Figure 3. Proposed Zeppelin Spinner Machine

Buk Ita (Cassava Crackers)
Buk Ita's dominant wastes defect (23.7%), motion (17.8%), and waiting (16.4%)—were driven by weather dependency and inefficient spatial organization. Workers frequently moved between scattered stations, while uneven drying resulted in high product rejection rates. The improvement centered on a parallel linear layout with a covered drying area directly connected to mixing and molding sections. This configuration reduced unnecessary motion and simplified supervision (see Figure 4).

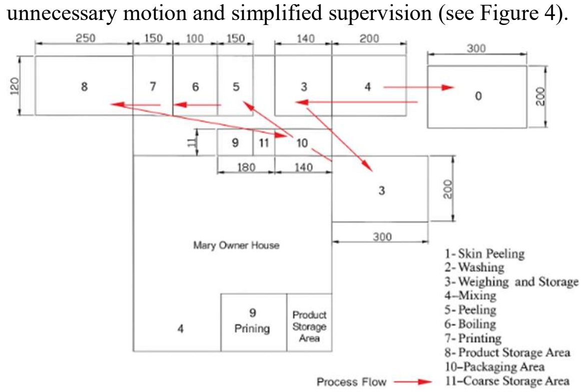

Figure 4. Proposed Layout for Buk Ita

The installation of a tray dryer standardized drying conditions (see Figure 2), cutting waiting time and defect waste by almost 50%. Additionally, replacing the outdated grinder improved dough uniformity, thereby eliminating the need for reprocessing (see Figure 5 for proposed smoothing machine). The redesign elevated PCE from 57.95% to 91.88% and improved hygiene compliance by providing an enclosed, cleanable surface that prevented dust and insects from entering the drying zone.

https://doi.org/10.25077/TEKNOSI.v11i3.2025.235-243

Figure 5. Proposed Smoothing Machine

Rizka (Onion Cookies)

Rizka exhibited defect (19.6%), motion (18.2%), and process waste (14.8%) due to manual dough cutting and redundant handling. The proposed U-shaped compact layout (see Figure 6) reorganized the workspace so that mixing, frying, and packaging were placed along a single continuous path. This design reduced travel distance by 28%, eliminated backtracking, and supported real-time supervision.

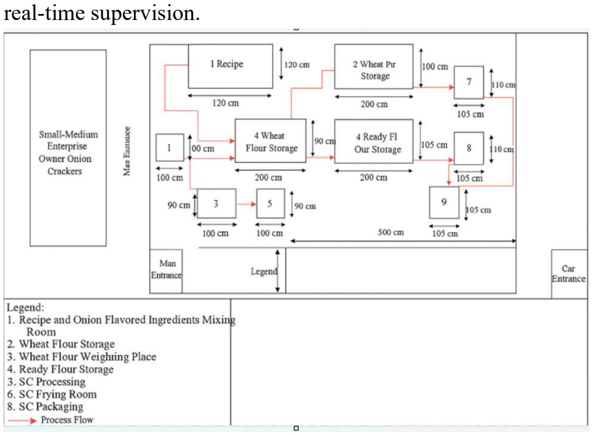

Figure 6. Proposed Layout for Rizka

The introduction of a food processor (Figure 7), molding tool (Figure 8), and gas fryer (Figure 9) optimized product uniformity and reduced process waste. Defect rates decreased by 20%, while hygiene compliance improved as manual handling and open frying were replaced with controlled equipment. The overall PCE increased from 64.76% to 81.60%, confirming that even minor ergonomic improvements can yield measurable operational and hygiene benefits.

Integrated Impacts of Improvements

Across all three enterprises, layout reorganization and low-cost mechanization collectively reduced total lead time by 40–50%, minimized motion and transportation waste by 30–35%, and improved GMP compliance scores by one categorical level. Financially, all improvements were feasible and quickly recoverable: Arsyila's investment of IDR 46.8 million achieved a one-month payback; Buk Ita's IDR 63.9 million investment achieved a 2.7-month payback with a positive Net Present Worth (NPW) of IDR 825 million; Rizka's IDR 14.8 million investment provided immediate returns with minimal financial risk.

Figure 7. Proposed Food Processor

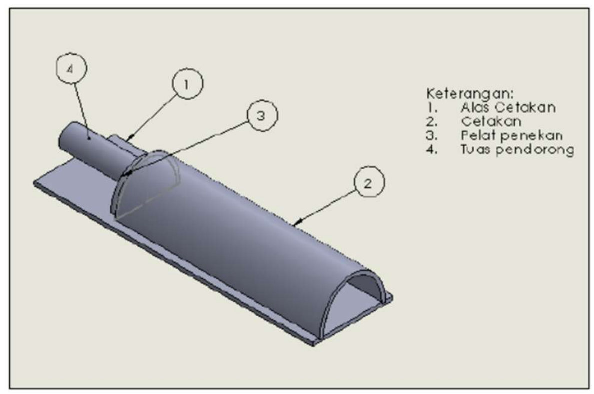

Figure 8. Proposed Molding Tool

Figure 9. Proposed Gas Fryer

These results demonstrate that tailored process reorganization and small-scale mechanization are highly effective for micro industries. Rather than relying on costly automation, small enterprises can achieve significant productivity and hygiene gains through incremental, evidence-based improvements aligned with Lean-GMP principles.

4.3. *Practical, Theoretical, and Sustainability Implications*

From a practical perspective, this study demonstrates that integrating Lean and Good Manufacturing Practice (GMP) can improve both production efficiency and food safety in resource-constrained environments. The applied interventions—tray dryers, spinners, ergonomic layouts, and workflow standardization—are low-cost, replicable solutions for other small-scale food producers. These results contribute to the growing evidence that structured Lean approaches can be successfully scaled down for micro-industrial applications without compromising GMP compliance.

From a theoretical standpoint, the findings support previous research by [20], [21], which emphasizes the adaptability of Lean principles to labor-intensive settings. The integration of GMP extends Lean's original focus on efficiency to include hygiene and safety, making the model particularly suitable for the food sector. The observed synergy between process discipline (Lean) and hygiene control (GMP) suggests a new hybrid operational paradigm for micro enterprises—"Lean-Hygienic Production Systems"—that addresses both productivity and sanitation holistically.

Regarding sustainability, the interventions contribute to three dimensions: economic, environmental, and social. Economically, the short payback periods ensure long-term feasibility. Environmentally, covered drying systems reduce contamination, waste generation, and energy loss. Socially, redesigned layouts and ergonomic aids enhance worker safety, comfort, and hygiene awareness. Together, these impacts confirm that the adoption of Lean-GMP supports sustainable industrial upgrading for small-scale food enterprises.

4.4. Limitations and Future Research Directions

Despite the promising results, several limitations were identified. First, the research was conducted on three case studies within similar cultural and geographic contexts, which may limit the generalizability of the findings. Second, implementation relied heavily on manual supervision rather than digital monitoring, meaning future improvements could benefit from low-cost Internet of Things (IoT) integration for real-time data collection. Third, while process and hygiene outcomes were quantified, long-term performance stability after several production cycles remains to be evaluated.

Future research should focus on expanding Lean-GMP applications across various food sectors to test the model's scalability. Longitudinal studies can examine the sustainability of improvements over time, while comparative benchmarking can identify best practices across regions. Additionally, integrating environmental indicators—such as water consumption, energy use, and carbon footprint—would strengthen the sustainability assessment. Collaboration between academic institutions, local governments, and small enterprise associations will be essential to transform Lean-GMP from an operational model into a standardized national framework for small-scale food industries.

Overall, the discussion demonstrates that Lean Manufacturing and Good Manufacturing Practice (GMP) integration offers a coherent and adaptable framework for improving both efficiency and hygiene in small-scale food enterprises. The findings from Arsyila, Buk Ita, and Rizka confirm that simple, low-cost interventions—such as optimized layouts, semi-mechanized tools, and standardized workflows—can yield substantial reductions in waste and tangible gains in product quality, worker safety, and sustainability. More importantly, the success of these interventions highlights the critical role of managerial discipline, continuous training, and cultural adaptation in sustaining long-term improvements.

The next chapter concludes this study by synthesizing the key findings and formulating practical recommendations for future implementation. It summarizes how Lean-GMP integration can serve as a replicable improvement model for other small-scale food industries, guiding policymakers, practitioners, and researchers seeking to enhance productivity, hygiene compliance, and industrial competitiveness in developing regions.

5. Acknowledgment

The authors would like to express their sincere gratitude to the Department of Industrial Engineering, Faculty of Engineering, Universitas Andalas, for the financial support provided through the Research Funding Program under Contract No. B/72/UN16.09/SPK/PT.01.03/RKAT-UNAND/2025. This support has been instrumental in the successful completion of this research.

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BIODATA PENULIS

Ahmad Syafruddin Indrapriyatna
Dosen Departemen Teknik Industri, Fakultas Teknik, Universitas Andalas sejak tahun 1991. Menamatkan Pendidikan S1 – S3 di Institut Teknologi Bandung. Pernah menjadi Ketua Jurusan Teknik Industri, Pembantu Dekan III Fakultas Teknik, Ketua Lembaga Pengembangan Teknologi Informasi dan Komunikasi, dan Dekan Fakultas Teknologi Informasi. Semua jabatan diemban di Universitas Andalas.

Reinny Patrisina
Dosen Departemen Teknik Industri, Fakultas Teknik, Universitas Andalas sejak tahun 1999. Menamatkan Pendidikan S1 di Universitas Andalas, S2 di Institut Teknologi Bandung, dan S3 di Prince Songkla University Thailand. Pernah menjadi Kepala Laboratorium Tata Letak dan Fasilitas Pabrik di Departemen Teknik Industri.