Unified Systems Approach for Human centered Operations (USAHO)
Vol. 1, No. 1, June 2026, Page 51-68
***e*-ISSN: XXXX-XXXX**

Reducing Dirty Oil Waste in Biscuit Moulding through 5S, GMP, and Quality Control Circle Implementation

Allysha Diva Canceria[1]*, Mitha Fitriani Caniago[2], & Fathir Muhammad Frihas[3]
[1]*Politeknik ATI Padang, Indonesia, [2]Universitas Bina Nusantara, Indonesia, [3]Universitas Bina Bangsa, Indonesia
*Co e-mail: allyshadiva25@gmail.com[1]

Article Information
Received: August 24, 2026
Revised: September 29, 2026
Online: October 22, 2026

Keywords
5R, Dirty Oil Waste, GMP, Moulding Process, Quality Control Circle

ABSTRACT
The food manufacturing industry faces challenges in managing production waste, including dirty oil waste generated during the moulding stage of biscuit production. This study evaluates the implementation of 5R principles (Sort, Set in Order, Shine, Standardize, and Sustain) and Good Manufacturing Practices (GMP) through a Quality Control Circle (QCC), locally known as Gugus Kendali Mutu (GKM), approach to reduce dirty oil waste. The study was conducted on a biscuit crackers production line at PT X, a national-scale biscuit manufacturer in Indonesia, during March–August 2026 using a case-study and action-research design based on the eight-step GKM cycle within the Plan-Do-Check-Action framework. Data were collected through field observations, direct weighing, stratification, Pareto analysis, and fishbone diagrams. Initial identification showed that dirty oil waste from the gauge roll unit reached 594 kg over four weeks (0.12% of production output), while total dirty waste generated during January–April 2026 amounted to 20,610 kg. Root-cause analysis identified four dominant factors: Man, Method, Machine, and Environment. Four improvement measures were implemented: a residual-oil processing unit, two-stage mesh filtration, a centrifugal separator, and a valve-equipped tray-mount modification, with a total investment of IDR 15,215,250. Post-implementation evaluation indicated that dirty oil waste decreased from 0.12% to nearly 0%, meeting the established SMART improvement target. These findings indicate that integrating 5R, GMP, and GKM can contribute to reducing production waste and improving process control in food manufacturing. However, the economic benefits, including cost savings and investment payback, as well as the environmental impact of the improvements, require further evaluation.

DOI: http://doi.org/10.69855/usaho
Available online at website: https://gpijournal.com/index.php/usaho

This work is licensed under a Creative Commons Attribution 4.0 International license

INTRODUCTION

The food manufacturing industry has grown rapidly alongside increasing demand for ready-to-consume processed products, including biscuits, wafers, and crackers. This growth in production volume has been accompanied by an increase in process waste generated at every production stage, from raw-material receiving and dough mixing to moulding, baking, and packaging. Ledezma and Posada-Correa (2023) affirm that the implementation of Good Manufacturing Practices (GMP) in mould-based forming processes contributes significantly to energy efficiency and reduced waste of production resources.

One type of waste that frequently escapes the attention of quality management is dirty oil waste formed by the pressing of dough on the gauge roll unit during the moulding stage. Residual oil from dough pressing that adheres to the surface of the forming rolls is generally discarded directly into the washing-room drain without any reuse process, potentially resulting in material losses as well as environmental pollution risk if disposed of without adequate treatment. Buwono et al. (2025), studying crude-oil waste treatment processes, confirm that material, method, and work-environment factors contribute significantly to quality failures in oil-waste treatment.

The 5S principles (Seiri/Sort, Seiton/Set in order, Seiso/Shine, Seiketsu/Standardize, and Shitsuke/Sustain), implemented in Indonesian plants as 5R (Ringkas, Rapi, Resik, Rawat, Rajin), have been widely demonstrated to be effective in reducing waste across various manufacturing sectors. Shahriar et al. (2022) report that implementing 5S in a plastic-bag manufacturing company in Bangladesh reduced operational time by up to 18% in the printing process by eliminating excess motion and waiting time. Donomai and Pinto (2023) show that a 5S program at an assembly company in Manaus, Brazil, improved productivity, reduced waste, and enhanced teamwork and occupational safety. Nevertheless, Oktafiani and Subiyantoro (2022) note that the success of 5S implementation strongly depends on the intensity of training and periodic internal audits, as achievement tends to remain below 50% without them.

In addition to 5S, the Quality Control Circle (QCC) approach, known in Indonesia as Gugus Kendali Mutu (GKM), is a widely applied participatory method for collaboratively solving quality problems on the shop floor. Meirizha and Kristina (2021) demonstrate that QCC implementation in the crude palm oil industry effectively improved product quality levels. Sulaeman et al. (2024) report a reduction in the rejection rate of precision-bored parts from 35% to 5% through QCC techniques in a crankshaft manufacturing industry. A recent study by Budiansyah et al. (2026) shows that the QCC method successfully reduced seat-frame front-cushion defects to zero without compromising safety, delivery accuracy, or employee morale. Meanwhile, Indrawan et al. (2026) emphasize the importance of training and visual management boards in simultaneously improving employee understanding of QCC practices, 5S culture, and workplace safety in an automotive component manufacturing company.

Although the literature on 5S, GMP, and QCC/GKM implementation across various manufacturing sectors is fairly extensive, including plastic injection moulding industries (Nurhadi & Arista, 2025; Aziz et al., 2025; Haberchad & Salih-Alj, 2025; Costa et al., 2021; Vongpeang et al.,

This work is licensed under a Creative Commons Attribution 4.0 International license

2024), automotive industries (Jou et al., 2022; Maulana et al., 2025), and vegetable-oil industries (Zaid & Nasrul, 2025; Yodpijit et al., 2025; Afriani & Suparno, 2025), studies that specifically integrate 5S and GMP through a GKM approach to reduce dirty oil waste in the biscuit moulding process remain very limited. Most prior research has focused on solid waste, dimensional defects, or material losses measured against finished-product weight, while liquid waste in the form of residual oil from the dough-forming process has not been comprehensively examined using the eight-step GKM framework. A study that links the three approaches to a measurable liquid-waste outcome is therefore needed.

The three approaches address different layers of the same problem and are treated here as one integrated framework. 5S provides the workplace order and discipline needed to separate recoverable material from waste and keep the area clean; GMP defines the hygiene and contamination-control conditions under which recovered material may be handled in a food plant; and GKM provides the participatory, stepwise mechanism through which a team turns 5S and GMP findings into measurable improvements. In the host company, the share of closed GMP/5S findings is a formal key performance indicator that stood far below target (see Results), which motivated the use of GKM in the moulding area (Indrawan et al., 2026; Oktafiani & Subiyantoro, 2022).

The novelty of this study lies in this integration and its outcome rather than in the individual tools, which are well established. It applies 5S, GMP, and the eight-step GKM cycle jointly to a liquid waste stream, dirty oil from the gauge roll, that to our knowledge has not been examined in earlier biscuit-moulding studies. It also moves from waste reduction to waste recovery by converting the oil into a cleaning soap, and it reports the pH, microbiological, and swab evidence used to approve that soap for internal cleaning.

This study is guided by three research questions: (RQ1) Which sources contribute most to dirty oil waste in the moulding line, and what are their root causes? (RQ2) How can 5S and GMP principles be operationalized through the eight-step GKM cycle to recover dirty oil? (RQ3) To what extent do the resulting improvements reduce dirty oil waste at the gauge roll unit, and is the recovered product suitable for internal cleaning use? Accordingly, the study aims to identify and stratify the sources of dirty oil waste, analyze their root causes using the Man, Method, Machine, and Environment approach, design and implement solutions grounded in 5S and GMP through the GKM cycle, and measure the effect on dirty oil volume and on the quality of the recovered soap.

METHODS

1. Research Design

This study employed a case-study design grounded in participatory action research, carried out by a Quality Control Circle (GKM) team and following the eight-step Quality Control Circle (GKM) cycle: (1) determining the activity/theme, (2) identifying causes, (3) determining solutions, (4) planning improvement, (5) implementing the improvement plan, (6) evaluating the solution, (7) establishing standardization, and (8) determining the next theme. This eight-step framework is an elaboration of the Plan-Do-Check-Action (PDCA) cycle widely used in QCC-based quality-

This work is licensed under a Creative Commons Attribution 4.0 International license

improvement research (Sulaeman et al., 2024; Budiansyah et al., 2026; Ponda & Suyanto, 2026). The steps were organized into three action-research cycles. In Cycle 1 (Plan, steps 1–4), baseline measurement and stratification led to cause analysis, solution selection, and an implementation plan, whose output was the four selected solutions. In Cycle 2 (Do and Check, steps 5–6), the solutions were implemented and dirty oil weights were compared with the baseline, and the result determined whether the solutions were retained. In Cycle 3 (Action, steps 7–8), the retained solutions were converted into standard work procedures and the next theme was determined; the output of each cycle served as the input of the next.

2. Location, Object, and Period of the Study

The study was conducted on a biscuit crackers production line in the moulding area of a biscuit plant operated by PT X. The company name, exact location, and specific line and machine codes are withheld throughout this article in accordance with a non-disclosure agreement between the research team and the company. The research object was focused on the gauge roll units of two moulding lines, with coded Line A and Line B, as the dominant sources of dirty oil waste. The study was carried out over the March–August 2026 period by a Quality Control Circle team, namely OPTIMA Team (Optimization of Waste Utilization and Area Quality), consisting of five members with an average attendance rate of 100% across five formal meetings.

The OPTIMA team consisted of five members, namely a production unit head, a quality control (QC) laboratory analyst, a QC hygiene and sanitation officer, and two production operators, guided by a GKM facilitator. The unit head led the design of the work pieces, the analyst and the hygiene officer prepared materials and ran the laboratory and swab tests, and the operators measured and fabricated the work pieces. Operators and production-area supervisors also took part in the focus group discussions.

3. Data Sources and Collection Methods

Primary data were obtained through: (a) direct observation of the moulding process during production shifts; (b) direct weighing of dirty oil waste using a digital scale with a resolution of 0.01 kg; (c) focus group discussions with operators and production-area supervisors; (d) pH measurement and microbiological analyses of the recovered soap and of swab samples from plastic boxes, performed in the QC microbiology laboratory; and (e) field work documentation. Secondary data were obtained from daily and monthly waste reports and weekly refined, bleached, and deodorized (RBD) oil output records of the production area for the January–April 2026 period as baseline data, together with the company's first-semester 2026 quality Key Performance Indicator (KPI) report. Direct weighing and laboratory tests provided the quantitative data, while observation, discussions, and documentation provided the process context.

4. Instruments and Analytical Tools

The analytical instruments used included check sheets, stratification diagrams, Pareto

This work is licensed under a Creative Commons Attribution 4.0 International license

diagrams to rank dirty waste categories by contribution, cause-and-effect (fishbone/Ishikawa) diagrams to identify root causes under the Man, Method, Machine, and Environment categories, a 5W2H matrix (What, Why, Where, When, Who, How, How much) to structure the improvement plan, and a risk-analysis matrix (likelihood × severity) to rank potential failures of the selected solutions and set mitigation priorities. These tools were selected because line operators can use them without advanced statistical training. This combination of basic quality-control tools is a common approach in prior QCC/GKM and Lean Six Sigma research (Tsarouhas & Sidiropoulou, 2023; Larisang et al., 2025; Kudo et al., 2025).

5. Data Analysis Procedure

Data analysis was carried out descriptively and quantitatively through the following stages: (1) tabulation of dirty waste data by category and calculation of relative and cumulative percentages to construct the Pareto diagram used for theme selection; (2) stratification of dirty oil waste by source (gauge roll and spray oil) and calculation of the ratio to production output; (3) identification of direct and indirect causes through group discussions with the GKM team, captured in a fishbone diagram; (4) determination of the best solution through an alternative-comparison matrix based on concept, technical design, fabrication and installation duration, cost, and solution effectiveness; (5) preparation of an implementation plan using a 5W2H matrix together with an implementation schedule; (6) evaluation of improvement results by comparing dirty oil waste volume before and after implementation against the previously established SMART (Specific, Measurable, Achievable, Reasonable, Time-bound) target; and (7) descriptive comparison of the pH and microbial counts of the recovered soap and of the swab results. Because the evaluation was a single before–after comparison of weighed totals and replicate measurements were not available, no inferential statistical test was applied.

6. Research Objective and Target

The research objective was formulated using the SMART framework, namely reducing dirty oil waste at the gauge roll units of moulding Line A and Line B from a baseline of 0.12% (594 kg per four weeks) to 0% by the end of the GKM period. The target was 100% processing of the oil collected at these units through the unit designed by the team, so that no oil would be discarded to the drain. Achievement was judged against the oil weighed at the gauge roll units during the four-week evaluation (weeks 22–25 of the GKM schedule), taking into account the 0.01 kg resolution of the digital scale.

RESULTS

1. Overview of the Research Object

PT X is a national-scale biscuit and wafer manufacturing company in Indonesia. In general, the organizational structure of the Quality Control Department comprises several functional units, including a unit overseeing the quality control laboratory. This study was carried out by a Quality

This work is licensed under a Creative Commons Attribution 4.0 International license

Control Circle, namely OPTIMA Team (Optimization of Waste Utilization and Area Quality) for publication purposes, formed in March 2026 and consisting of five members with tenure ranging from 6 months to 5 years, under the guidance of a GKM facilitator. The team's vision is to apply zero-waste principles through innovative processing of oil waste into a reusable product, while reducing environmental pollution through effective and efficient oil-waste management.

As organizational context, the Key Performance Indicator (KPI) "Percentage of Closed GMP/5R Findings" (5R being the company's term for 5S) in the first-semester 2025 target-setting report shows that actual achievement in February 2026 reached only 33.33% against a minimum target of 95% (Category A), placing it in Category E (below 60%). This performance gap constitutes part of the rationale for systematically strengthening 5S and GMP implementation through a GKM approach in critical areas, including the moulding process. The moulding area was therefore used as a site where the three approaches could be applied together with measured results.

2. Identification and Stratification of Dirty Waste

Observation data on production-line dirty waste for the January–April 2026 period (Table 1) show a total dirty-waste volume of 20,610 kg, comprising six categories: dirty flour, dirty dough, dirty sugar, dirty sago, dirty oil, and dirty skin waste. Table 1 reflects the routine monthly records of all dirty waste in the production line, so the dirty oil category (1,654 kg) covers every point at which oil was discarded and is distinct from the dedicated four-week weighing at the gauge roll units reported in Table 2. Monthly totals ranged from 3,126.45 kg in April to 6,410.5 kg in February.

Table 1. Production Line Dirty Waste Data, January–April 2026 (kg)

Category	January	February	March	April	Total (kg)	Relative (%)	Cumulative (%)
Dirty Flour	1,448.3	1,908.0	2,185.4	1,068.9	6,611	32.1	32.1
Dirty Dough	1,434.5	1,682.0	1,679.5	892.5	5,689	27.6	59.7
Dirty Sugar	650.8	1,641.5	1,164.5	621.55	4,078	19.8	79.5
Dirty Sago	516.0	658.0	751.5	362.0	2,288	11.1	90.6
Dirty Oil	330.0	521.0	621.25	181.5	1,654	8.0	98.6
Dirty Skin	81.0	179.5	7.0	24.0	292	1.4	100.0
Total	**4,379.6**	**6,410.5**	**6,402.15**	**3,126.45**	**20,610**	**100.0**	–

Source: QC Department field observation data, processed (2026).

Stratification results using a Pareto diagram (Figure 1) show that dirty flour waste was the largest contributor (32.1%; 6,611 kg), followed by dirty dough waste (27.6%; 5,689 kg), dirty sugar waste (19.8%; 4,078 kg), dirty sago waste (11.1%; 2,288 kg), dirty oil waste (8.0%; 1,654 kg), and dirty skin waste (1.4%; 292 kg). The first four categories account for 90.6% of the volume, and dirty oil brings the cumulative share to 98.6%. These categories were then screened for recoverability, as discussed below.

This work is licensed under a Creative Commons Attribution 4.0 International license

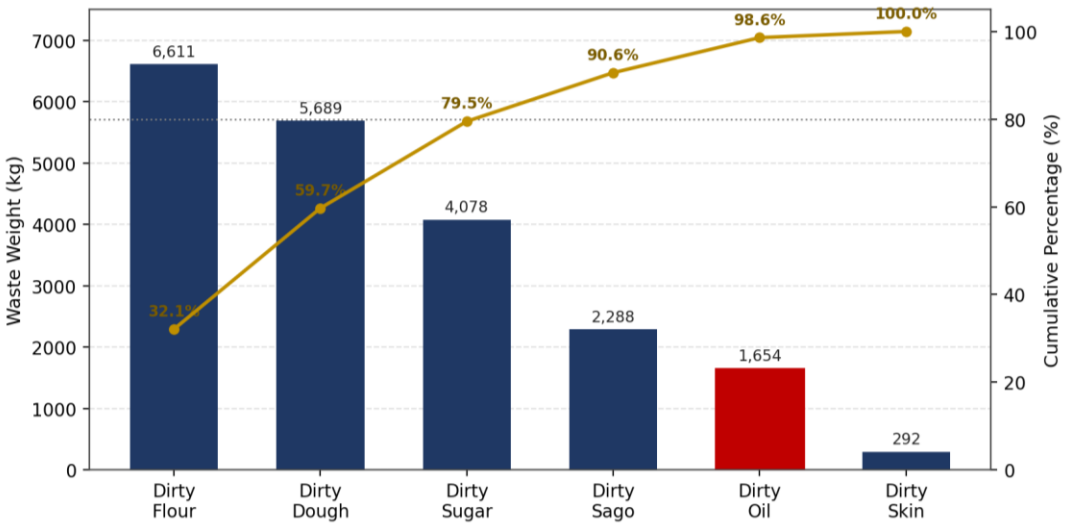


Figure 1. Pareto Chart of Production Line Dirty Waste (January–April 2026)

Although dirty oil waste ranks fifth in proportion (8.0%), the Pareto ranking was combined with a screening of recoverability to select the improvement theme. Dirty flour, dough, sugar, sago, and skin waste are categorized as "dirty" because they have fallen onto the production floor and become contaminated, requiring disposal. Dirty oil waste, in contrast, is "dirty" only because it is mixed with residual dough during the pressing process, so in principle it can still be separated and reused if handled with an appropriate method. Its main source is also concentrated at one point, the gauge roll unit, which makes a before-and-after comparison by weighing feasible (Table 2). For these reasons dirty oil was selected as the improvement theme, consistent with the view of Buwono et al. (2025) that opportunities to reuse liquid production waste are frequently overlooked compared to solid waste.

3. Stratification of Dirty Oil Waste in the Moulding Area

Further stratification of dirty oil waste was conducted to determine the focus area for improvement. Observation data over four weeks show that dirty oil waste originates from two main points, namely the gauge roll unit and the spray oil unit (Table 2). Weights were recorded for four consecutive weeks with a digital scale, and the four-week total at each source was expressed as a percentage of RBD oil output for the same period.

Table 2. Stratification of Dirty Oil Waste by Source (4-Week Observation)

Source	Week 1 (kg)	Week 2 (kg)	Week 3 (kg)	Week 4 (kg)	Total (kg)	Percentage of Output (%)
Gauge Roll	172	138	118	166	594	0.12
Spray Oil	13	15	13.5	16	57.5	0.04

Source: GKM team field observation data, processed (2026).

This work is licensed under a Creative Commons Attribution 4.0 International license

The gauge roll unit contributed 0.12% of RBD oil output (594 kg of the 485,032 kg produced over the same four weeks), far higher than the spray oil unit, which contributed only 0.04% (57.5 kg). Based on this stratification, the GKM team set the gauge roll units of moulding Line A and Line B as the main focus of improvement, with an estimated daily waste generation of 30–50 kg per day that had previously been discarded without further processing. Tables 1 and 2 differ in scope and period: Table 1 summarizes routine monthly records of all dirty oil in the production line, whereas Table 2 reports a dedicated four-week weighing at the two oil sources, so the 594 kg baseline should not be read as a share of the 1,654 kg.

4. Determination of the Improvement Theme and Target

Based on the Pareto ranking, the recoverability screening, and the stratification results, the GKM team established the theme "Optimizing the Use of Dirty Oil Waste through Utilization of Dirty Oil from the Gauge Roll of Moulding Line A & Line B, from 0.12% to 0%, for the Period March–August 2026." The improvement target was formulated using the SMART framework: it was specific (processing dirty oil waste in the Line A and Line B moulding process), measurable (reducing dirty oil waste from 0.12% to 0%), achievable (100% oil-waste processing), reasonable (attainable through measurable improvement solutions), and time-bound (March–August 2026). The theme thus links a measurable baseline (0.12%, or 594 kg per four weeks) to a defined end state and period.

5. Root Cause Analysis

Root-cause analysis was carried out using a cause-and-effect (fishbone) diagram that grouped the causes of dirty oil waste into four categories: Man, Method, Machine, and Environment (Figure 2). Direct and indirect causes were proposed by team members in group discussions and then checked against field measurements. Each category was linked to a measured observation, as described below.

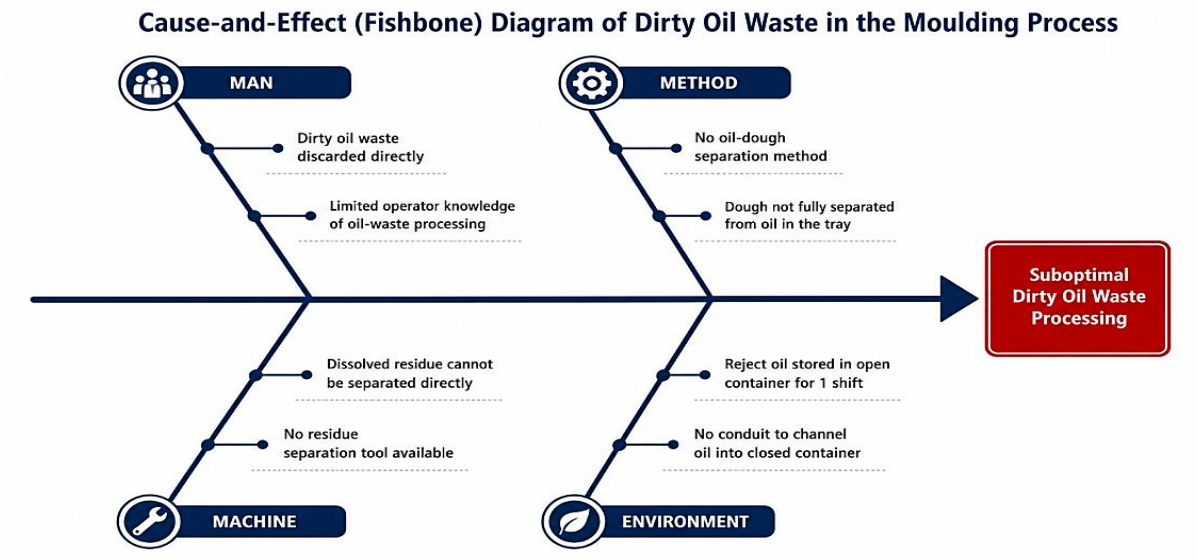


Figure 2. Cause-and-Effect (Fishbone) Diagram of Dirty Oil Waste in the Moulding Process

This work is licensed under a Creative Commons Attribution 4.0 International license

Under the Man category, the team identified that dirty oil waste had previously been discarded directly without processing due to operators' limited knowledge of oil-waste processing methods. Observation data over four weeks show a consistent waste volume in the range of 118–172 kg per week (Table 2), indicating that no reuse effort existed under the pre-existing conditions. The collected oil was placed in a plastic bag and poured into the washing-room drain.

Under the Method category, it was found that dough had not been fully separated from oil in the collection tray due to the absence of an adequate separation method between the upper and lower gauge roll pressing outputs. Measurements across three production shifts (Table 3) show an average of 7.66 kg of oil still mixed with dough per shift, with an average total mixed dough of 3.64 kg. Dough and oil therefore left the collection tray as one mixture that could not be reused directly.

Table 3. Oil Mixed with Dough and with Dissolved Residue in the Collection Tray (3 Shifts)

Shift	Oil mixed with dough (kg)	Total dough (kg)	Oil mixed with dissolved residue (kg)	Total residue (kg)
1	7.31	3.45	3.99	0.99
2	7.23	3.55	4.35	1.26
3	8.43	3.93	3.78	0.84
Average	**7.66**	**3.64**	**4.04**	**1.03**

Source: GKM team field measurement, February 2026.

Under the Machine category, dissolved residue was found that could not be separated directly from the oil without additional treatment. Measurements across three shifts (Table 3) show an average of 4.04 kg of oil mixed with dissolved residue per shift, with an average total residue of 1.03 kg. Because the residue is dissolved, it passes through screening and requires a separate separation step.

Under the Environment category, it was found that rejected dirty oil waste was stored in an open container for one full work shift before disposal, causing the oil to lose usability due to prolonged exposure to open air. A microbiological check of oil kept in an open plastic bag for one shift supported this concern: S. aureus reached 470 CFU/g (colony-forming units per gram) against a maximum standard of 100 CFU/g, and yeast and mold counts were too numerous to count against a maximum of 200 CFU/g, while total plate count (60 CFU/g; maximum 1,000), Enterobacter (0 CFU/g; maximum 10), and coliform (<3 MPN/g; maximum <3) remained within standard. Open storage therefore lowered the hygienic quality of the oil and was identified as one of the factors that limited reuse unless the oil was promptly handled with a closed container and an adequate conveyance system.

All four root causes were subsequently confirmed through repeated field observation and were determined to be valid and important contributors to the main problem, namely the suboptimal processing of dirty oil waste in the moulding process. The Man, Method, and Machine causes were supported by weight and residue measurements (Tables 2 and 3), and the Environment cause by the microbiological check of stored oil. Together they indicated that the oil was recoverable in principle but was lost for lack of knowledge, separation steps, equipment, and closed handling.

This work is licensed under a Creative Commons Attribution 4.0 International license

6. Formulation and Selection of Improvement Solutions

Based on the four root causes, the GKM team formulated two alternative solutions for each cause and selected the best one using a comparison matrix based on concept, design, fabrication/installation duration, cost, and effectiveness. For example, the team chose a centrifugal separator over a settling tank because settling took a long time, and chose two-stage mesh in the reservoir over a mesh above the tray because it gave a more optimal filtration result. The selected solutions are described below.

Four solutions were selected, one for each root cause. The first two addressed the Man and Method causes: (1) a 100-liter residual-oil processing unit with a 500–1,000 rpm drive motor, used to mix the recovered oil, potassium hydroxide (KOH), and water into a cleaning soap named Oilea for the production and sanitation teams, and (2) two-stage 40-mesh and 60-mesh stainless steel filtration in the oil-collection reservoir to separate oil from dough particles. The other two addressed the Machine and Environment causes: (3) a centrifugal separator (four 1-liter bottles; 1,000–2,000 rpm) to remove dissolved residue, and (4) a modification of the oil-tray mount with a ¾-inch valve and a 150 cm hose to channel oil into a closed reservoir, thereby reducing exposure to open air.

The total investment for the four solutions amounted to IDR 15,215,250, of which 84.7% (IDR 12,893,200) was allocated to the residual-oil processing unit as the primary solution, followed by the centrifugal separator (IDR 1,546,000; 10.2%), the two-stage mesh filtration (IDR 623,000; 4.1%), and the tray-mount modification (IDR 153,050; 1.0%). No analysis of disposal savings, soap-purchase savings, or payback was made because the required cost data were not available to the team; this is discussed as a limitation. The processing unit therefore dominated the budget, whereas the other three solutions together cost IDR 2,322,050.

7. Risk Analysis and Preventive Actions

Each selected solution was analyzed for potential risk using a likelihood × severity matrix, with both factors scored from 1 (low) to 5 (high), together with preventive and corrective actions (Table 4). Scores of 15 or more were classified as high, 7–12 as medium, and 6 or less as low, and mitigation priority followed the category. No risk was classified as high; motor failure, valve leakage, mesh tearing, and hose leakage were medium and bearing wear and mount shifting were low. Preventive measures include periodic inspection at the start and end of each shift, routine lubrication of moving components, and component replacement according to the usage cycle.

Table 4. Risk Analysis, Preventive and Corrective Actions, and Mitigation Priority

Solution	Potential risk	L	S	Score	Category	Preventive and corrective action	Priority
Oil processing unit	Motor failure	2	4	8	Medium	Prevent: periodic inspection and oil check. Correct: add oil.	2
Oil processing unit	Valve leakage	3	3	9	Medium	Prevent: periodic inspection and scheduled valve replacement. Correct: replace valve.	2

This work is licensed under a Creative Commons Attribution 4.0 International license

Two-stage mesh filtration	Mesh tearing	3	3	9	Medium	Prevent: inspection at start and end of each shift. Correct: replace mesh.	2
Centrifugal separator	Bearing wear	3	2	6	Low	Prevent: routine lubrication and inspection. Correct: replace worn bearing.	3
Tray-mount modification	Shifted mount position	2	2	4	Low	Prevent: position check at start and end of each shift.	3
Tray-mount modification	Hose or valve leakage	3	3	9	Medium	Prevent: start/end-of-shift inspection. Correct: replace hose and valve.	2

L, likelihood; S, severity; Priority 1 is the highest.

8. Implementation of the Improvement Plan

Implementation was carried out using a 5W2H matrix (What, Why, Where, When, Who, How, How much), with activities scheduled according to the Plan-Do-Check-Action framework over approximately 24 weeks during the March–August 2026 period. Steps 1–4 (Plan) took place in weeks 14–19, step 5 (Do) in weeks 19–21, step 6 (Check) in weeks 22–25, step 7 (standardization) in weeks 26–33, and step 8 (next theme) in weeks 34–37. The oil processing unit was installed in week 21 and the centrifugal separator in week 23, both in the biscuit process area, while the two-stage mesh was installed in week 22 at the gauge roll finish oil reservoir and the tray modification in week 24 at the gauge roll finish tray. The implementer competencies prepared included material design capability, material preparation, and measurement and fabrication of work pieces, involving five team members with distinct roles for each solution, and the resources prepared included stainless-steel plates, mesh material, drive motors, valves, hoses, and welding, cutting, and drilling equipment.

9. Evaluation of Improvement Results

Evaluation was carried out during the four-week Check phase (weeks 22–25 of the GKM schedule), after the processing unit had been installed and while the remaining solutions were being completed. Over these four weeks the digital scale (resolution 0.01 kg) recorded no dirty oil waste at the gauge roll units (0 kg; 0.00% of RBD oil output), compared with the baseline of 594 kg per four weeks (0.12% of output); any oil that escaped weighing was below the 0.01 kg resolution of the scale. This represents a substantial reduction and meets the SMART target of processing all oil collected at the gauge roll units. No statistical test was applied because the evaluation was a single before–after comparison of weighed totals.

This corresponds to a 100% reduction of measurable dirty oil waste at the studied source points within the four-week evaluation window. The result was achieved without major changes to

This work is licensed under a Creative Commons Attribution 4.0 International license

the layout or speed of the production line. It does not by itself demonstrate cost efficiency, because no cost-saving data were collected; this point is addressed in the Discussion.

10. Recovery of Residual Oil into Oilea Soap and Its Validation

The residual oil collected at the gauge roll units was processed into a cleaning soap named Oilea in the 100-liter mixer tank, using the filtered and centrifuged oil, potassium hydroxide (KOH), and water. At dilutions of 1:2 and 1:3 (one part soap to two or three parts water) the pH was 9.73 and 9.72, respectively, and the soap sample showed no growth of total plate count, Enterobacter, yeast and mold, or S. aureus (0 CFU/g) and coliform below 3 MPN/g (most probable number per gram), based on one result per parameter. Trial washing of hands and plastic boxes produced foam and removed visible residue from the boxes; this observation was descriptive and was not quantified. The soap was used for cleaning hands, plastic boxes, and factory equipment.

Swab results for plastic boxes are summarized in Table 5. After sanitation, boxes cleaned with Oilea showed lower Enterobacter (30 vs 260 CFU/cm²) and S. aureus (40 vs 410 CFU/cm²) than boxes cleaned with the comparison soap OB, equal yeast and mold (0 CFU/cm²), and a slightly higher total plate count (920 vs 720 CFU/cm²); Oilea therefore performed in a comparable range to soap OB rather than a demonstrably better one, and no statistical comparison was possible. Before cleaning, total plate count, Enterobacter, and S. aureus were too numerous to count; after cleaning with Oilea they fell to 340, 10, and 20 CFU/cm², and mold was no longer detected, although yeast (60 CFU/cm²) remained. Counts therefore remained detectable, so Oilea is positioned as a cleaning soap and not as a disinfectant, and routine sanitation remains necessary.

Table 5. Swab Results of Plastic Boxes (CFU/cm²; Coliform in MPN/cm²)

Parameter	Before cleaning	After cleaning	After sanitation, Oilea	After sanitation, soap OB
Total plate count	TNTC	340	920	720
Enterobacter	TNTC	10	30	260
Yeast / mold	90 / 30	60 / 0	0	0
S. aureus	TNTC	20	40	410
Coliform	4	<3	<3	<3

TNTC, too numerous to count. Source: QC microbiology laboratory and GKM team (2026).

Use of Oilea was approved internally by the QC, health-safety-environment (HSE), and hygiene and sanitation functions for cleaning purposes only (hands, plastic boxes, and factory equipment). The approval is not a formal product certification. Wider use would require additional validation.

DISCUSSION

1. Effectiveness of Combining 5S and GMP in Reducing Waste

The findings of this study reinforce empirical evidence in the literature that combining 5S

This work is licensed under a Creative Commons Attribution 4.0 International license

principles with GMP effectively reduces waste in manufacturing processes. The reduction in dirty oil waste from 0.12% to 0.00% (below the 0.01 kg scale resolution) is consistent with Shahriar et al. (2022), who reported an 18% reduction in operational time through the elimination of excess motion and waiting time in a plastic-bag industry, and with Donomai and Pinto (2023), who demonstrated increased productivity and reduced waste through 5S implementation. In this study, sorting (Seiri) separated recoverable oil through screening and centrifugation; set in order (Seiton) fixed the flow from tray to closed reservoir through the valve and hose; shine (Seiso) removed a contamination source by ending open storage; standardize (Seiketsu) is represented by the new work procedures (GKM step 7); and sustain (Shitsuke) by shift-start and shift-end inspections. GMP contributed cross-contamination control (Ledezma & Posada-Correa, 2023) and the microbiological checks and internal approval of the soap, while GKM provided the eight-step cycle that tied these elements together.

Nevertheless, as noted by Oktafiani and Subiyantoro (2022), the success of 5S implementation strongly depends on the intensity of training and periodic audits. In this study, this aspect is reflected in the performance gap in the company's closed GMP/5S findings KPI, which remained in Category E (33.33%) prior to the GKM intervention in the moulding area, underscoring the importance of area-specific improvement as a leverage point for overall organizational performance. This suggests that the technical solutions need continuing training and audits to be sustained.

2. The Role of GKM as a Participatory Quality-Improvement Method

The GKM approach in this study was proven to be effective in facilitating systematic and participatory root-cause identification, because each root cause was linked to a measurement made by the team (Tables 2 and 3). This finding is consistent with Meirizha and Kristina (2021), who demonstrated the effectiveness of QCC in improving crude palm oil product quality, as well as Sulaeman et al. (2024), who reported a reduction in the rejection rate of precision-bored parts from 35% to 5%. Budiansyah et al. (2026) similarly reported zero seat-frame cushion defects without compromising safety, delivery accuracy, or employee morale.

Compared with the Define–Measure–Analyze–Improve–Control (DMAIC) approach in Six Sigma, which emphasizes statistical process-capability analysis (Tsarouhas & Sidiropoulou, 2023; Jou et al., 2022; Larisang et al., 2025), the GKM approach in this study relies on work-group participation and simple analytical tools that line operators can use without advanced statistical expertise, consistent with Indrawan et al. (2026). Their view is that QCC success depends largely on operators' understanding of basic quality-improvement methods. This suits the production-line setting of this study.

Both participatory and statistical methods have been shown to work in other manufacturing sectors, including Kaizen with 5S, Kanban, and Value Stream Mapping in injection-moulding-machine manufacturing (Patel & Kiran, 2022), Lean Six Sigma in mechanical manufacturing and jacking-pipe production (Duc & Thu, 2022; Ly & Viet, 2022; Zhafira et al., 2022), and PDCA in jewelry

This work is licensed under a Creative Commons Attribution 4.0 International license

casting (Chan et al., 2024). The choice of GKM in this study was therefore contextual: it suited the small scale of the problem, the limited analytical resources at the production-line level, and the need for rapid, participatory problem solving without sacrificing the depth of root-cause analysis. Both families of methods therefore remain valid options for similar problems.

3. Comparison with Other Studies on Oil and Process-Liquid Waste Management

The recovery of dirty oil into a cleaning soap adds a recovery perspective to the literature on liquid-waste management in oil- and fat-based industries, which has mostly addressed oil losses and defects rather than reuse. Muttaqin and Aryanny (2024) reported that Six Sigma and Kaizen implementation reduced oil-dirt defects by up to 11.9% in cosmetic bottle packaging, Imtinan and Cahyaputri (2024) used Value Stream Mapping to identify waste on a transparent bar-soap production line, and Afriani and Suparno (2025), Yodpijit et al. (2025), and Zaid and Nasrul (2025) addressed oil losses and product quality in large-scale palm-oil and cocoa-oil industries. These studies mainly addressed defects and losses, whereas the reuse pathway examined here is less common in the reviewed literature.

4. Managerial Implications and Sustainability

From a managerial perspective, the results suggest that integrating 5S, GMP, and GKM can remove a measurable waste stream at the gauge roll units and turn it into an internal cleaning soap, with potential cost and environmental benefits. These benefits are potential only: the investment of IDR 15,215,250 is known, but the volume and price of the soap replaced, the disposal cost avoided, and the payback period were not available to the team because these data are held by other divisions. Tsarouhas and Sidiropoulou (2023) showed that DMAIC implementation in an olive-packaging process produced annual savings through reduced weight variation and rejection rates, which indicates the type of analysis that should follow this study. In environmental terms, the 594 kg of oil per four weeks previously discarded to the drain was no longer discarded during the evaluation, and the Green Lean Six Sigma approach of Rizkika et al. (2025) offers a direction for quantifying such benefits.

Sustaining the program requires standardizing new work procedures (the seventh GKM step) and conducting periodic monitoring to ensure that target achievement is maintained in the long term, as emphasized by Saha and Mahmud (2022) and Hafiz and Ernawati (2025) in the context of sustained lean-tools implementation in the plastic manufacturing industry. Kudo et al. (2025) similarly indicate that basic quality tools can be transferred to other food production lines, so the program can be extended to other process units that generate oil or process-liquid waste. Without such controls, the observed gains may not persist.

5. Limitations and Directions for Further Research

This study has several limitations. First, the evaluation was a single four-week before–after comparison on one production line, without a control line or inferential statistics. Second, the

This work is licensed under a Creative Commons Attribution 4.0 International license

evaluation weeks (22–25) overlapped with the installation of the mesh filtration, the centrifugal separator, and the tray modification (weeks 22–24). Third, the economic and environmental benefits are potential only, because no data on soap volume, avoided soap purchases, disposal costs, or payback were available; future research should include cost–benefit and life-cycle analyses. Fourth, the pH, microbiological, and swab results come from a limited number of tests, and Oilea was approved internally for cleaning only, so broader use would require replicate testing and formal validation. Fifth, the study was carried out in one plant, so generalization should be made with caution.

CONCLUSIONS

This study analyzed the effectiveness of implementing 5S and GMP in reducing dirty oil waste in the moulding process through a Quality Control Circle (GKM) approach on the gauge roll units of moulding Line A and Line B, a biscuit crackers production line at PT X, a biscuit manufacturing company whose identity is withheld. Dirty oil was the fifth-largest category of production-line dirty waste (1,654 kg; 8.0% of 20,610 kg during January–April 2026), and a separate four-week weighing recorded 594 kg of dirty oil at the gauge roll units (0.12% of RBD oil output). Root-cause analysis identified four dominant factors: limited waste-processing knowledge (Man), the absence of an oil-dough separation method (Method), limited dissolved-residue separation equipment (Machine), and open-storage conditions that reduced oil usability (Environment).

The four technical solutions designed and implemented — a residual-oil processing unit, a two-stage mesh filtration system, a centrifugal separator, and a valve-equipped tray-mount modification — required an investment of IDR 15,215,250 and were followed by no measurable dirty oil waste at the gauge roll units during the four-week evaluation (0 kg, below the 0.01 kg scale resolution), compared with 594 kg per four weeks at baseline, which meets the SMART target. The recovered oil was converted into Oilea cleaning soap, which had a pH of about 9.7 and showed no detectable microbial growth in the sample tested, and which was approved internally for cleaning use. These findings support the view that integrating 5S, GMP, and GKM can eliminate a liquid waste stream in moulding-based food manufacturing, while the economic and environmental benefits remain potential and still need to be quantified.

Recommendations for the management of similar industries include: (1) expanding replication of this approach to other process units with the potential to generate oil or process-liquid waste; (2) standardizing new work procedures and providing continuous operator training to sustain achievement; and (3) conducting cost–benefit analysis (soap volume and price, avoided disposal, payback) and integrating the GKM approach with statistical process-capability analysis in further research to strengthen the long-term validity of the results. Future research is also recommended to expand the scope of locations and monitoring duration to improve the generalizability of the findings. Management support for training and periodic audits remains a precondition, as the company's KPI gap shows.

This work is licensed under a Creative Commons Attribution 4.0 International license

REFERENCES

Afriani, D. L., & Suparno, S. (2025). Integration of Six Sigma and Fuzzy FMEA to reduce oil losses in the crude palm oil (CPO) processing industry in Central Kalimantan. International Journal of Social Service and Research, 5(6), 638–649. https://doi.org/10.46799/ijssr.v5i6.1269

Aziz, K., Pranata, J., Alam, I. C., Ramadhani, F., Burhanudin, A. Z., & Prastyo, Y. (2025). Quality control in plastic injection manufacturing at PT. Minebea Accesssolution Indonesia: The number of NG scratch. Review: Journal of Multidisciplinary in Social Sciences, 2(1), 1–7. https://doi.org/10.59422/rjmss.v2i01.705

Budiansyah, M. R., Suwarno, A., & Syahliantina, A. (2026). Analisis Pengendalian Kualitas Produk Seat Frame Front Cushion Menggunakan Metode Quality Control Circle (QCC) pada PT TBA. INSOLOGI: Jurnal Sains dan Teknologi. https://doi.org/10.55123/insologi.v5i1.7635

Buwono, E. W. S., Yusup, M., & Atmaja, D. A. S. P. (2025). Analisis Faktor – Faktor Berpengaruh Pada Proses Treatment Pengolahan Limbah Minyak Mentah Pada PT. Wastec Internasional. Venus: Jurnal Publikasi Rumpun Ilmu Teknik. https://doi.org/10.61132/venus.v3i3.961

Chan, Y., Leonardo, Y., Supriatna, A., & Faturachman, D. (2024). The effect of quality control standard implementation for quality improvement of the casting process on the jewellery manufacturing industry. Journal of Research and Technology. https://doi.org/10.55732/jrt.v10i1.1206

Costa, A., Ferreira, L., Silva, F., Sa, J. C., Pereira, M., & Avila, P. (2021). Analysis and improvement in the Electrical Discharge Machining process used on the manufacturing of moulds for plastics injection moulding. IOP Conference Series: Materials Science and Engineering. https://doi.org/10.1088/1757-899x/1193/1/012021

Donomai, N. K. A., & Pinto, F. R. (2023). Application of methodology 5s in an industrial assembly company in the City of Manaus, AM. International Journal for Innovation Education and Research. https://doi.org/10.31686/ijier.vol11.iss2.4090

Duc, M. L., & Thu, M. (2022). Application of Lean Six Sigma for Improve Productivity at The Mechanical Plant. A Case Study. Manufacturing Technology. https://doi.org/10.21062/mft.2022.028

Haberchad, O., & Salih-Alj, Y. (2025). Quality Control and Process Optimization of Injection Molding using a Data-Oriented Approach in an Industrial Setting. Journal of Data Science and Intelligent Systems. https://doi.org/10.47852/bonviewjdsis52024730

Hafiz, M., & Ernawati, A. D. (2025). Analysis Of Plastic Pellets Production Process To Reduce Waste Using Lean Six Sigma Method And FMEA. Jurnal Sistem Cerdas. https://doi.org/10.37396/jsc.v8i1.499

Imtinan, I., & Cahyaputri, B. (2024). Waste Identification Using the Value Stream Mapping (VSM) Method on the PT XYZ Transparent Bar Soap Production Line. Jurnal Teknologi dan Manajemen. https://doi.org/10.52330/jtm.v22i1.194

This work is licensed under a Creative Commons Attribution 4.0 International license

Indrawan, M., Efendi, Y., Maharani, D. K. S., & Raya, C. (2026). Implementasi QCC pada Penerapan Budaya 5R dan Safety di PT Rapu. Bhakti Karya dan Inovatif. https://doi.org/10.37278/bhaktikaryadaninovatif.v6i1.1486

Jou, Y., Silitonga, R., Lin, M., Sukwadi, R., & Rivaldo, J. (2022). Application of Six Sigma Methodology in an Automotive Manufacturing Company: A Case Study. Sustainability. https://doi.org/10.3390/su142114497

Kudo, S. Y., Isa, D. R., & Payu, M. R. F. (2025). Application of Statistical Quality Control and Failure Mode and Effect Analysis to Improve Panada Tore Quality at PT. Cita Rasa Pagimana. Journal of Mathematics, Computations and Statistics. https://doi.org/10.35580/jmathcos.v8i1.6708

Larisang, Sanusi, Hamid, A., Hasibuan, R. P., & Sugito, E. (2025). Performance Enhancement in Injection Moulding Manufacturing: A Case Study Utilizing the DMAIC Methodology. Mathematical Modelling of Engineering Problems. https://doi.org/10.18280/mmep.120415

Ledezma, J. M., & Posada-Correa, J. C. (2023). Definition and evaluation of good manufacturing practices for plastic injection molding. Energy Efficiency. https://doi.org/10.1007/s12053-023-10103-x

Ly, M., & Viet, Q. N. K. (2022). Improvement Productivity and Quality by Using Lean Six Sigma: A Case Study in Mechanical Manufacturing. International Research Journal on Advanced Science Hub. https://doi.org/10.47392/irjash.2022.066

Maulana, M. T., Ayu, D., Sari, P., Kindangen, L. A., Setiawan, Y., & Prastyo, Y. (2025). Pengaplikasian 5S dan Kaizen Sebagai Upaya Peningkatan Kualitas Produksi Area Spot Welding di Perusahaan Manufaktur Otomotif. Journal of Science, Technology, and Innovation. https://doi.org/10.65310/09hxkp86

Meirizha, S., & Kristina, D. (2021). Analisis kecacatan produk crude palm oil (CPO) menggunakan metode quality control circle (QCC) pada PT. Ramajaya Pramukti. Jurnal Surya Teknika. https://doi.org/10.37859/jst.v8i1.2616

Muttaqin, N. U. A., & Aryanny, E. (2024). Defect Analysis of Packaging Bottle Products Using Six Sigma and Kaizen Methods at PT. XYZ. IJIEM - Indonesian Journal of Industrial Engineering and Management. https://doi.org/10.22441/ijiem.v5i1.22420

Nurhadi, D. A., & Arista, A. (2025). Perbaikan kualitas mold proses injection molding pada PT Giken Precision Indonesia. Computer and Science Industrial Engineering (COMASIE). https://doi.org/10.33884/comasiejournal.v12i3.9790

Oktafiani, I. S., & Subiyantoro, S. (2022). Application of 5S Management in Improving the Quality of Furniture Production in Meubel Karya Agung of Ponorogo Regency. PALAPA. https://doi.org/10.36088/palapa.v10i1.1658

Patel, M., & Kiran, M. B. (2022). Implementation of Kaizen principles in an injection molding machine manufacturing company. Proceedings of the 7th North American International Conference on Industrial Engineering and Operations Management. IEOM Society International. https://doi.org/10.46254/na07.20220390

This work is licensed under a Creative Commons Attribution 4.0 International license

Ponda, H., & Suyanto, S. (2026). Enhancing Insert Lifetime in Side Cutting of Special Nut Products Using The QCC Method to Reduce Cost Per Piece. Heuristic. https://doi.org/10.30996/heuristic.v22i2.132876

Rizkika, A. D., Salomon, L., & Kosasih, W. (2025). Pendekatan Green Lean Six Sigma untuk minimisasi limbah dalam produksi produk gelas di industri peralatan plastik rumah tangga. Jurnal Mitra Teknik Industri. https://doi.org/10.24912/jmti.v4i1.34601

Saha, R. K., & Mahmud, F. (2022). Lean Tools and Techniques for Improving Production Performance and Waste Reduction in A Plastic Company: A Case Study. Proceedings of the International Conference in Industrial & Mechanical Engineering and Operations Management (IMEOM). https://doi.org/10.46254/bd05.20220091

Shahriar, M. M., Parvez, M., Islam, M., & Talapatra, S. (2022). Implementation of 5S in a plastic bag manufacturing industry: A case study. Cleaner Engineering and Technology. https://doi.org/10.1016/j.clet.2022.100488

Sulaeman, S., Misaran, M. S., Farm, Y. Y., & Chua, B. (2024). Quality Control Circles Technique for Reducing Fine Bored Parts Rejects After Tool Change. Proceeding of the International Conference on Multidisciplinary Research for Sustainable Innovation. https://doi.org/10.31098/icmrsi.v1i.804

Tsarouhas, P., & Sidiropoulou, N. (2023). Application of Six Sigma methodology using DMAIC approach for a packaging olives production system: a case study. International Journal of Lean Six Sigma. https://doi.org/10.1108/ijlss-06-2022-0140

Vongpeang, S., Sonsanam, A., Sripanom, T., & Angboonta, P. (2024). Reducing Black Spot Waste from Motor Housing Parts- Model EM-14 with Qc7 Quality Tools. Nanotechnology Perceptions. https://doi.org/10.62441/nano-ntp.v20i3.17

Yodpijit, S. N., Wangrakdiskul, S., Charoensuk, N., Phromphat, K., & Boonmee, C. (2025). Sustainable Quality Transformation In Agro-Industrial Manufacturing: A Six Sigma–Kaizen Model For Thailand's Crude Palm Oil Sector. Jurnal Riset Ilmu Teknik. https://doi.org/10.59976/jurit.v3i2.195

Zaid, S., & Nasrul, N. (2025). Application of the Six Sigma Method to Improve the Quality of Cocoa Oil Industry Products in Southeast Sulawesi Province, Indonesia. Journal of Global Innovations in Agricultural Sciences. https://doi.org/10.22194/jgias/25.1464

Zhafira, A., Fitriana, R., & Mayusda, I. (2022). Quality improvement and waste minimization in the production process of 450 mm jacking pipe using the Lean Six Sigma method. Proceedings of the 3rd Asia Pacific International Conference on Industrial Engineering and Operations Management. IEOM Society International. https://doi.org/10.46254/ap03.20220211