Implementation of Single-Minute Exchange of Die (SMED) for Reducing Extruder Downtime in Pet Food Production

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Abstract

In the pet food manufacturing industry, effective use of machinery is essential for maintaining competitiveness. In dry pet food production, the extrusion process is often the main bottleneck in the production line. This study aims to improve the overall performance of the extruder by applying Single Minute Exchange of Die (SMED) to reduce die changeover time and cleaning time. A Pareto analysis was used to identify the major causes of machine downtime that most affect production performance. The SMED methodology was implemented through actual operational procedures focused on reducing die changeover time. The results demonstrate that the successful application of SMED led to a substantial improvement in machine availability increase of 6.88%. (from 62.12% to 69.00%) and consequently, the OEE improved from 58.22% to 64.67%, an increase of 6.45% These findings underscore the significant potential of lean-based process improvement initiatives to enhance production performance and provide practical guidance for practitioners seeking to optimize extrusion operations in similar manufacturing environments.

1 Introduction

The pet food industry faces increasing competitive pressure driven by changing consumer preferences, higher nutritional expectations, and rising raw material and energy costs. These challenges require manufacturers to improve operational efficiency while maintaining consistent product quality. In dry pet food production, the extrusion process critically influences production capacity and overall performance.

Extruders often become production bottlenecks due to unplanned downtime and low equipment availability, negatively affecting throughput and costs. This study aims to improve extruder effectiveness by applying the Single-Minute Exchange of Die (SMED) methodology to systematically reduce changeover and setup downtime, increase equipment availability, and support long-term operational efficiency and sustainability.

1.1 SMED Overview

The SMED methodology, designed to minimize machine setup times, is crucial for enhancing manufacturing efficiency across various sectors, including automotive and food production. Wahyudi and Setiawan highlight that employing SMED principles can lead to significant enhancements in the efficiency of processes, such as punch changeover in manufacturing settings, by reducing internal activities that contribute to downtime [1]. In automotive contexts, Niekurzak et al. underscore that shortening changeover times positively impacts overall production efficiency, thereby facilitating waste reduction and promoting sustainability [2]. These findings can similarly be extrapolated to dry pet food extrusion, where minimizing downtime is critical.

Research by Cahyadi reviews different approaches to optimizing mold changeover times through SMED, focusing on the distinction between internal and external activities [3]. Notably, it identifies that many inefficiencies stem from the internal setup tasks that could be transitioned to external setups occurring while the machine is operational. This principle can be adapted in pet food extrusion to streamline production transitions.

Additionally, Salah and Sobhi stress that the proactive structuring of production processes using lean manufacturing techniques allows for effective minimization of non-value-added time, which can be particularly beneficial in the dynamic environments of food production [4]. They assert that the successful implementation of SMED results in reduced changeover durations, which aligns with the broader objectives of lean methodologies, highlighting the need for a structured approach in operational management [4].

In the specific context of dry pet food extrusion, Rasib et al. emphasize the importance of enhancing flexibility and response times in manufacturing operations, especially targeting changeover downtimes [5]. Their study suggests that through the application of SMED principles, operations can better adapt to the flavors and formulations needed in pet food production, which often requires frequent production line changes.

Flavourings provides foundational insight into extrusion processing, highlighting its importance in achieving desired nutritional profiles in pet food. Consequently, downtime affects not only production volume but also product quality and safety due to delayed processing, underscoring the need for efficient changeovers [6][7].

Despite its benefits, implementing SMED in dry pet food extrusion presents challenges. Transitioning from traditional to lean practices requires comprehensive training and cultural change, as prolonged changeovers often result from non-standard procedures and inadequate preparation [3]. Management support is therefore essential to foster a lean culture. Additionally, rapid changeovers must balance efficiency with stringent food safety requirements, which remain critical and non-negotiable in pet food manufacturing [8].

2 Objectives and Methodology

The case study was conducted at XX Co., Ltd. (pseudonym used for confidentiality), a medium-sized dry pet food manufacturing facility in Thailand. The factory specializes in premium extruded dry pet food for dogs and cats, focusing primarily on chicken-based formulations made from fish meal and natural ingredients. This study applies the Single-Minute Exchange of Die (SMED) methodology to reduce extrusion die changeover and cleaning time in the dry pet food production line.

2.1 *Loss Analysis*

From the selected factory case study, Figure 1 (a) shows the extrusion process plays a critical role in industrial pet food manufacturing. The analysis of production capacity and downtime losses identifies extrusion as the key bottleneck, with the lowest capacity of 114 tons per day. This limitation is further supported by the Pareto analysis show in Sub-figures (b), which shows that extrusion-related losses account for the largest share of total downtime, with changeover time being the top loss contributor accounting for 1,028.68 hours or approximately 45% of total downtime, indicating substantial potential for improvement through SMED-based setup and changeover reduction.

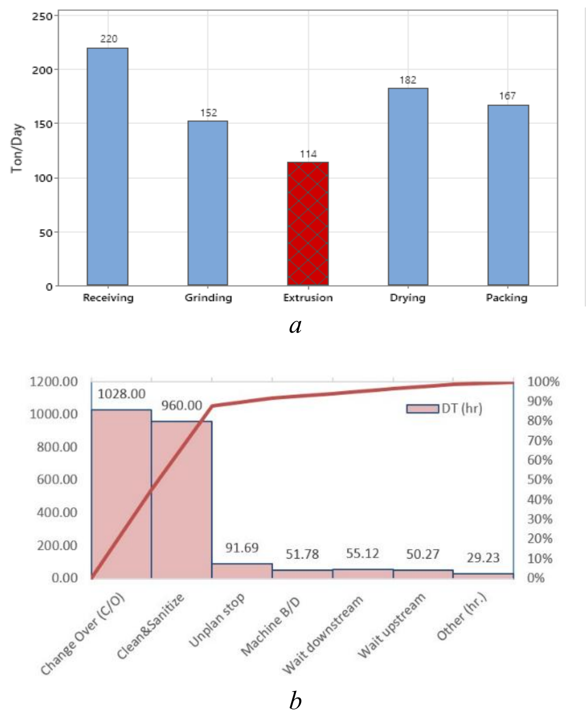

Fig. 1 (a) Process capacity analysis of each production stage in the dry pet food manufacturing line, (b) Pareto analysis of extrusion downtime losses.

To evaluate extrusion machine performance prior to improvement, overall equipment effectiveness (OEE) was analyzed as a key indicator of manufacturing efficiency. This analysis provides insight into actual operating conditions and identifies performance gaps requiring improvement.

The results show that equipment performance remains below the commonly accepted industrial benchmark of OEE > 85%, based on world-class manufacturing standards. Therefore, improvement planning is necessary, particularly to reduce machine downtime and enhance operational efficiency to support future capacity expansion and cost competitiveness.

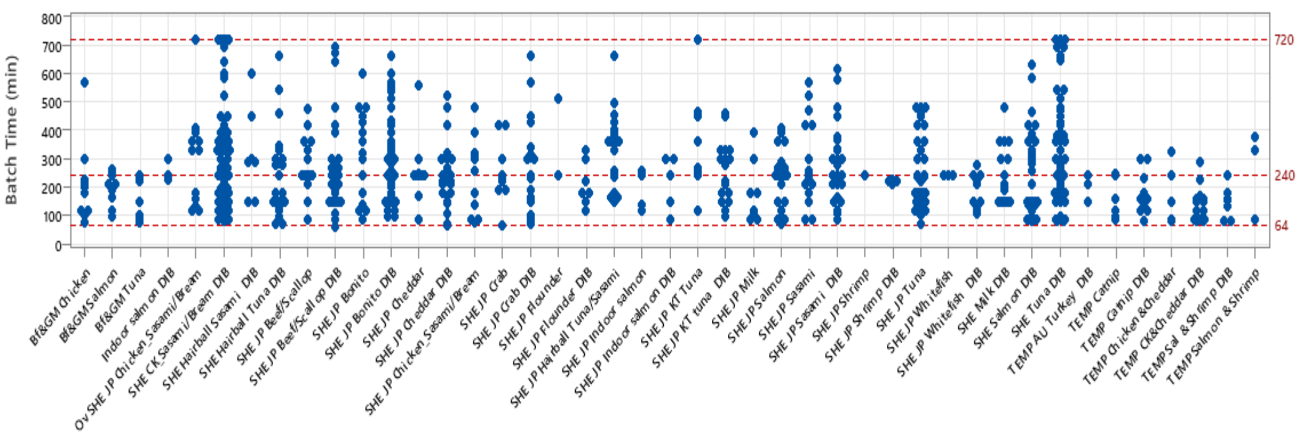

Fig. 2 Individual Value Plot of batch time showing batch-to-batch group variability

Figure 2 shows batch time variability, ranging from 64 to 720 minutes with a median of 240, alongside critical performance thresholds. The changeover (C/O) process involves two main variables: time and frequency, with ~435 changeovers annually. Since changeover time accounts for ~75% of total batch time, Therefore, changeover time was selected as the primary improvement focus, as it represents the largest contributor to production inefficiency.

The SMED technique is based on separating die change activities into **Internal** (can only be performed when the machine is stopped) and **External** (can be performed while the machine is running). The goal is to convert Internal activities to External where possible and to streamline steps to minimize machine downtime.

Fig. 3 provides a visual overview of the dry pet food extrusion line and key elements involved in die changeover. Left panel: Shows the overall extrusion room layout, including the main extruder unit and downstream conveyor system responsible for cooling, cutting, and conveying the extruded product. Right panel: Depicts the die assembly during setup or maintenance, illustrating the mechanical configuration, fastening points, alignment guides, and crane access required for die removal and reinstallation.

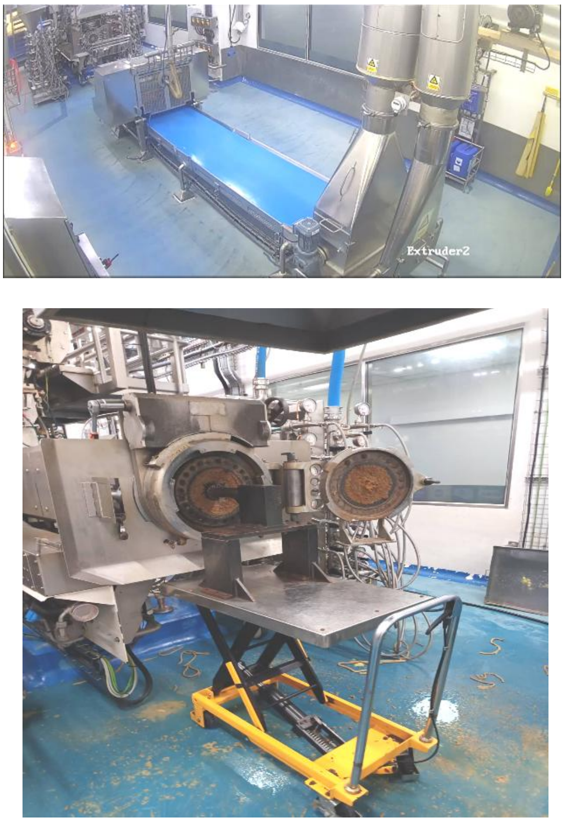

Fig. 3 Extrusion Line Overview and Die Setup Configuration

Table 1 analyzes die change activities by sub-steps, recording actual times to identify downtime sources and improvement opportunities. The key findings are summarized as follows:

1. Current State (Before Improvement) Details of sub-activities and their respective times.
2. SMED Analysis (Internal → External Conversion) Identification of Internal activities that can be converted to External.
3. After Improvement Resulting process after converting Internal to External and implementing improvements.

3 Results and Discussion

The SMED application targeted the primary downtime source die changeover (45% of total losses per Pareto analysis) achieving a substantial reduction in internal setup time and improved extruder availability and OEE.

Pre-Improvement (Current-State) Total changeover time was 186 min per occurrence, with 110 min internal (machine stopped) and 76 min external. Major inefficiencies included:

- Preparatory tasks embedded in internal activities (e.g., LOTO kit collection, tool searching, cleaning solution preparation).
- Waiting and sequential execution (e.g., setup mode delay, parameter configuration during restoration).
- Lack of standardization and workplace organization, leading to high changeover frequency (435/year) consuming 75% of batch time and limiting throughput to 114 tons/day.

3.1 Key Improvements Implemented through Smed Stages (Separation, Conversion, Streamlining)

1. Internal-to-external conversions: LOTO preparation, tool readiness, cleaning agents, and program pre-setting moved external using dedicated kits, shadow boards, and default modes.
2. Streamlining: Quick clamps + guide pins reduced die handling (20 min → 8 min each); automatic cleaning cycle isolated (30 min → 15 min); die sanitization parallelized by team (40 min → 25 min).
3. Implementation approach: Time studies + video analysis of multiple changeovers, team workshops, SOP development, operator training, and pilot trials—low-cost, no major equipment changes.

Post-Improvement Results Internal downtime per changeover reduced to 46 min (58% decrease), or 30–40 min under optimal conditions. Annual savings estimated at ~411 hours of downtime. This directly increased availability from 62.12% to 69.00% (+6.88%). The 58–73% reduction in changeover-related downtime is realistic for pet food extrusion, where strict sanitation limits full externalization (unlike non-food extrusion cases). The gains align with literature (e.g., 46% setup reduction in printing; 3–11% OEE uplift in related SMED studies) and demonstrate SMED's effectiveness in hygiene-constrained batch processes. The modest OEE improvement reflects that changeover was only one major loss category; remaining gaps (minor stops, speed losses) offer further potential. This structured, low-investment approach provides a replicable model for similar food extrusion lines facing frequent recipe changes, enhancing flexibility, capacity, and competitiveness without compromising food safety. Future steps could integrate TPM or 5S to target other Six Big Losses.

Table 1 SMED Activity Breakdown and Improvement Analysis for Extruder Die Changeover

No	Main Activity	Sub-Activities Performed (Current)	Time (min)	SMED Analysis / Waste Identified	Proposed Conversion / Improvement Action	Analyze	New Time (min)	Ext.	Saved
1	Lockout/ Tagout (LOTO) implementa-tion	Collect locks and tags (5) Isolate electrical/pneumatic/hydraulic energy (7) Safety verification (3)	15	Preparatory task; does not require machine stoppage	Prepare dedicated LOTO kit for each machine in advance pre-positioned	Ext. prep + Int. exec.	0 prep + 5 exec.	5	10
2	Switch machine to setup mode	Activate control system (4) Adjust plate position (6)	10	System waiting time; identified as waiting waste	Define and apply a default setup mode to eliminate waiting	Int.	5	-	5
3	Die removal	Search for tools/wrenches (4) Loosen die fastening bolts (8) Lift die using crane (6) to place (2)	20	Non-value-added searching and walking time	Implement shadow board and dedicated tool kit at workstation; use quick clamps	Int.	8	-	12
4	Automatic machine cleaning	Prepare water/cleaning solution (5) Automatic cleaning cycle (20) Cleanliness inspection (5)	30	Preparatory work performable in advance	Pre-prepare cleaning agents, cloths, and hoses before shutdown; isolate cycle only	Int.	15	-	15
5	Die cleaning and sanitiza-tion	Apply cleaning solution (10) Wipe with wet cloth (15) Air blow/drying (10) Condition inspection (5)	40	No conversion needed (already external)	Perform in parallel by dedicated team member(s)	Ext.	-	40	0
6	Die reinstallatio n	Lift die using crane (6) Die alignment adjustment (4) Tighten fastening bolts (8) Position verification (2)	20	Adjustment and fastening time (streamlinable)	Use guide pins + quick clamps for faster alignment and fastening	Int.	8	-	12
7	Machine shutdown	System shutdown (3) Safety verification (2)	5	No major waste; minimal opportunity	No change (essential safety step)	Int.	5	-	0
8	Product-ion area floor cleaning	Sweep/vacuum debris (15) Floor wiping (15)	30	No conversion needed	No change (already external)	Ext.	-	30	0
9	Prepare scrap collection equipment	Prepare containers (3) Position arrangement (3)	6	No conversion needed	No change (already external)	Ext.	-	6	0
10	Machine system restoration	System reset (4) Signal verification (4) Trial run (2)	10	Parameter/recipe configuration; setup not requiring physical access	Pre-set programs and recipes before stopping the machine; load preset only	Int.	5	-	5
		Total	186				46	81	59

Current State Summary

• Internal type consists of tasks that must be performed while the machine is stopped, Total: 110 minutes

• External type are tasks that can be performed without stopping the machine, Total: 76 minutes

After Internal → External Conversion and Improvements

• Total Internal time was reduced to approximately 46 minutes.

• External activities increased, but they do not contribute to machine downtime (81 min.)

Overall downtime was reduced by 59 minutes compared with the Current State.

Fig. 4 illustrates the key workplace organization and preparatory improvements introduced through the SMED methodology to support internal-to-external activity conversion, including standardized tool boards (a) and external setup carts with pre-staged materials (b, c).

a

b *c*

Fig. 4 (a) Standardized tool boards, (b) External setup carts, and (c) pre-staged materials

Future research could extend the SMED application to multiple production lines or facilities and incorporate a longer follow-up period to assess sustained benefits.

4 Conclusion

1. The application of SMED methodology successfully reduced die changeover-related downtime in the dry pet food extrusion process by converting internal setup activities to external ones and implementing lean improvements (quick clamps, shadow boards, preset programs), decreasing internal changeover time from 110 minutes to 30–40 minutes (a 60–70% reduction).
2. The study confirms the practical effectiveness and transferability of SMED in pet food extrusion operations with frequent recipe changes, offering a low-cost, structured framework that enhances production flexibility, throughput capacity, and long-term competitiveness without compromising food safety standards.

5 Acknowledgements

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6 References

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