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Development of a Semi-Automatic Curry Puff Machine using 3D Printer Mould for Small and Medium Industries: A CDIO Approach

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Abstract. This paper presents the development of a semi-automatic curry puff machine, emphasising a comparative analysis between 3D-printed and traditional plastic moulds. Guided by the CDIO (Conceive-Design-Implement-Operate) framework, the study investigates how each mould fabrication method impacts cost, customisation, food safety, and scalability within Small and Medium-sized Enterprises (SMEs). Manual curry puff production remains prevalent among SMEs, leading to labour inefficiencies and inconsistent output. By integrating rapid prototyping and user-centred design, this work demonstrates how 3D-printed moulds can overcome many challenges associated with conventional plastic moulds. Comparative economic analysis, durability testing, lifecycle assessment, and pilot feedback are presented. Results reveal that 3D-printed moulds offer significant advantages in customisation, lead time, and cost-efficiency for low-to-medium production volumes, while traditional plastic moulds remain favourable for large-scale, repetitive manufacturing. Discussion addresses food safety, regulatory compliance, and sustainability. The findings provide a replicable template for SME-focused food machinery innovation, aligning digital fabrication with industrial modernisation.

Keywords: curry puff machine, 3D printing, plastic mould, semi-automatic, food manufacturing

1. INTRODUCTION

Curry puffs are a staple snack enjoyed across Southeast Asia, characterized by their flaky pastry and flavorful fillings. Their widespread popularity has led to a thriving market, with increasing demand in both local and international contexts. Small and Medium-sized Enterprises (SMEs) play a pivotal role in meeting this demand, often forming the backbone of the curry puff supply chain, especially in countries like Malaysia, Singapore, and Thailand. Despite their importance, most of these SMEs still rely heavily on manual production techniques, particularly for processes such as dough shaping, filling, and crimping. These labor-intensive methods not only limit production capacity but also introduce inconsistencies in product quality and contribute to higher labor costs.

While industrial-scale, fully automated pastry production lines exist, they are frequently characterized by high capital investment, operational complexity, and large physical footprints, making them inaccessible to most SMEs. The lack of affordable, scalable automation options has created a significant bottleneck, where SMEs must choose between constrained growth or risk quality through poorly adapted mechanization. With the advent of Malaysia's New Industrial Master Plan (NIMP 2030) and the global push toward Industry 4.0, there is an urgent need for accessible, intermediate automation solutions that enable SMEs to modernize without sacrificing flexibility or financial sustainability.

A core challenge in semi-automating curry puff production lies in the fabrication of food-grade moulds for shaping and crimping the pastry. Traditionally, plastic moulds are manufactured using injection moulding or CNC machining, processes that require high upfront tooling costs and lengthy lead times. This not only restricts SMEs' ability to iterate or customize their products but also makes small-batch or seasonal product variations economically unfeasible.

The emergence of 3D printing (additive manufacturing) offers a transformative alternative. By enabling rapid, low-cost production of custom moulds, 3D printing allows SMEs to experiment with new designs, quickly adapt to market trends, and lower the barrier to entry for automated processes. However, questions remain regarding the durability, food safety, and long-term cost-effectiveness of 3D-printed moulds compared to conventional plastic moulds, especially when subjected to the rigours of daily food production.

This research addresses these challenges by systematically comparing the use of 3D-printed moulds and traditional plastic moulds in the development of a semi-automatic curry puff machine tailored for SMEs. The study is structured within the Conceive-Design-Implement-Operate (CDIO) framework to ensure a user-centered, iterative approach that balances economic, ergonomic, and food safety considerations. By directly evaluating cost, customization, production efficiency, regulatory compliance, and operational sustainability, this work aims to provide SMEs with clear, evidence-based guidance on the optimal mould fabrication strategy for their unique needs.

In doing so, this paper not only advances the field of SME-orientated food machinery design but also contributes to broader efforts in digital transformation and sustainable manufacturing practices within the food industry. Figure 1 shows the comparison between manual and semi-auto-curry puff machines.

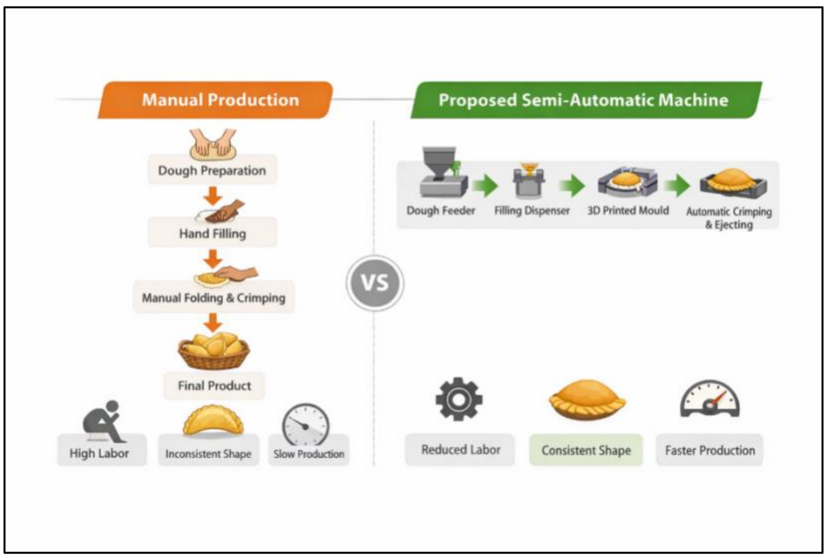

Figure 1. Comparison between manual and semi auto curry puff machine

2. Literature Review

The Conceive–Design–Implement–Operate (CDIO) framework provides a systematic mechanism for translating theoretical engineering knowledge into deployable industrial solutions, thereby addressing the long-standing theory–practice divide. This integration is particularly significant for small and medium-sized enterprises (SMEs), where innovation is frequently constrained by limited financial resources, technical capacity, and risk tolerance. Unlike traditional linear design models, CDIO emphasizes iterative development, experiential validation, and real-world testing, allowing technologies to mature within operational environments rather than remaining conceptual.

For SME-focused innovation, the framework supports practical decision-making by embedding feasibility, manufacturability, and usability considerations early in the development cycle. The conceiver phase focuses on identifying production inefficiencies and defining measurable technical requirements. During the design phase, engineering principles are translated into optimized system architectures that balance performance with cost constraints. The implement stage prioritizes functional prototyping and verification, while the operate phase evaluates reliability, user interaction, and long-term operational suitability. Collectively, these stages reduce adoption risk and improve technology readiness for smaller industrial settings.

In the present study, CDIO functions as the guiding structure for transforming additive manufacturing capabilities and mechanical design concepts into a semi-automatic curry puff machine tailored to SME production environments. The framework directly informs the methodological workflow from needs analysis and computer-aided design to prototype fabrication using food-grade 3D printed moulds and pilot-scale operational assessment ensuring that the resulting system is technically robust, economically viable, and scalable for industry applications.

2.1. CDIO Framework in Engineering Product Development

The Conceive-Design-Implement-Operate (CDIO) framework originated as an educational paradigm to bridge theory and practice in engineering (CDIO Initiative, 2021). It has evolved into a robust methodology for structured, user-centered product development, emphasizing iterative cycles, multidisciplinary collaboration, and real-world problem-solving. Noor et al. (2021) demonstrated that integrating CDIO with other systematic approaches like TRIZ can significantly enhance process optimization, quality assurance, and defect reduction in manufacturing contexts highly relevant for SMEs seeking to balance innovation with resource constraints. Recent literature underscores the CDIO framework's value in fostering sustainability, modularity, and stakeholder engagement in engineering projects (Tan et al., 2020). By embedding feedback loops, the CDIO approach enables rapid prototyping and continuous improvement, supporting SMEs in de-risking investments in new technologies and machinery. Figure 2 shows the CDIO Framework in Engineering Product Development.

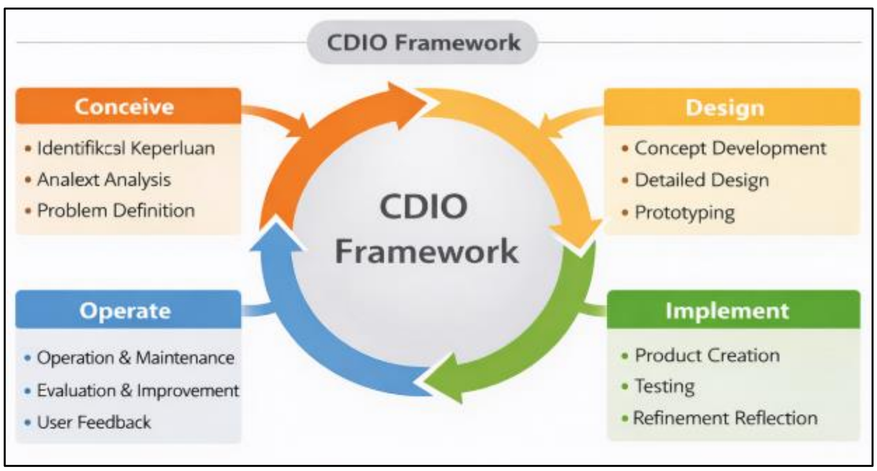

Figure 2. CDIO Framework in Engineering Product Development

2.2. Automation and Digital Transformation in SME Food Manufacturing

SMEs in the food sector face distinct challenges—limited capital, space, and technical expertise—which often preclude the adoption of fully automated, industrial-scale solutions (Tan et al., 2020; Sohel et al., 2025). Studies reveal that semi-automatic machines, which blend manual and automated operations, provide a practical pathway for SMEs to improve productivity, consistency, and operator safety while retaining the flexibility and artisanal qualities valued by their customer base (Ibrahim, 2010; RC Machinery, n.d.). Industry 4.0 technologies, including IoT and digital fabrication, are increasingly being tailored to SME needs. However, the shift from manual to semi-automatic processing still hinges on affordable and adaptable tooling, particularly in pastry and bakery sectors where product shapes are critical to brand identity and consumer acceptance (Ng Kok Wah, 2025).

2.3. Plastic Moulds in Food Processing Machinery

Traditional plastic moulds for food production are typically fabricated using injection moulding or CNC machining. These methods produce strong, durable, and smooth-surfaced moulds suitable for high-volume, repetitive manufacturing (Al-Bakri et al., n.d.). The major drawbacks are high initial tooling costs, long lead times, and minimal flexibility for design changes or customization (Bi et al., 2024). For SMEs, this often results in a reluctance to innovate or diversify product offerings, as each new design iteration incurs significant expense and time delays. Plastic moulds, when made from food-grade materials such as polycarbonate or certain high-density polymers, are recognized for their compliance with food safety standards and ease of cleaning (Mohamad Kamal & Sulaiman, 1970). However, their economic feasibility diminishes for short production runs or frequent model changes—a common scenario among SMEs responding to seasonal or niche markets.

2.4. 3D Printing (Additive Manufacturing) in Food-Grade Mould Fabrication

Additive manufacturing, especially 3D printing, has emerged as a disruptive force in the prototyping and small-batch production of food processing tools and moulds (Bi et al., 2024; Rinshana et al., 2024). 3D printing technologies such as Fused Deposition Modelling (FDM) and Stereolithography (SLA) enable the creation of complex, customized mould geometries at much lower costs and shorter lead times compared to traditional manufacturing (Sohel et al., 2025). Key advantages of 3D printing for food-grade moulds include: Rapid prototyping: Iterative design and testing can be performed within days, facilitating user-centered development and frequent product updates, customization: SMEs can easily modify mould shapes to cater to specific customer preferences or branding without incurring major costs, cost efficiency at low-to-medium volumes: Unlike injection moulding, where per-unit cost drops only at very high volumes, 3D printing remains economical for small batches and prototypes. Material selection is critical and food-safe 3D printing materials such as PETG, PLA, and certain nylon formulations are increasingly available, though they require careful certification and post-processing to ensure hygienic, non-porous surfaces (Drummer et al., 2012; Rinshana et al., 2024). Common post-processing techniques include sanding, chemical smoothing, and the application of food-grade epoxy coatings to prevent bacterial harbourage and to increase durability (Ng Kok Wah, 2025).

2.5. Comparative Studies: 3D-Printed vs. Traditional Plastic Moulds

Comparative research consistently finds that 3D-printed moulds outperform traditional plastic moulds in terms of flexibility, lead time, and upfront cost for small-scale or frequently changing production runs (Bi et al., 2024; Ng Kok Wah, 2025). However, for long-term, high-volume production, traditional plastic moulds retain advantages in surface finish, structural integrity, and longevity. Lifecycle assessments highlight that 3D printing generates less material waste for custom projects and is easier to recycle, supporting sustainability goals (Sohel et al., 2025). While food safety compliance is achievable for both mould types, 3D-printed moulds require more rigorous post-processing and validation to achieve the same standards of cleanability and durability (Drummer et al., 2012). Operator and SME feedback from pilot implementations indicate that the ability to quickly iterate and respond to market trends is a decisive advantage in competitive food sectors.

2.6. Research Gap

Although there is ample evidence of the potential of 3D printing in SME food manufacturing, few studies have systematically compared its practical performance and economic impact against traditional plastic moulds within the context of semi-automatic machinery. This gap is particularly significant in the pastry sector, where product shape and customization are tightly linked to commercial success.

3. Research Methodology

3.1. Materials Selection for 3D Printed Food Moulds

Selecting appropriate materials is crucial for food contact safety and durability. Common food-grade 3D printer filaments/plastics include:

PLA (Polylactic Acid): Biodegradable, generally food safe (check for certifications, avoid additives) and low heat resistance.
PETG (Polyethylene Terephthalate Glycol): Durable, chemical resistant, and FDA approved for certain food contact applications.

Nylon (Polyamide): High strength, but porous—surface sealing or use of food-grade coatings is often required.
PEI (ULTEM): High-performance and food safe and can withstand higher temperatures but require specialized printers.

Table 1. Comparison of 3D Printed Materials for Food Moulds

Material	Heat Resistance	Durability	Porosity	Cleaning Cycles (before degradation)	Remarks
PLA	Low (<60 °C)	Moderate	Low–Moderate	3–5	Easy to process but unsuitable for high-temperature food moulds.
PETG	Moderate (up to ~80 °C)	High	Low	10+	Stable after repeated cleaning cycles; suitable for cold or medium-temperature food moulds.
Nylon	Moderate (up to ~100 °C)	Very High	High	<5 (without coating)	Strongest material tested but absorbs oil/water; requires food-grade coating.
PEI (ULTEM)	Very High (>150 °C)	Very High	Very Low	20+	Most reliable and food-safe option; however, costly and requires specialized printers.
Ceramic/ Composite SLA Resins	Moderate	Low–Moderate	Very Low	10+ (indirect use)	Provides excellent surface resolution; best for indirect mould applications only.

Ceramic/Composite SLA resins: For indirect food contact (mould negatives).

Post-processing (sanding, chemical smoothing, food-grade epoxy coating) is often required to create non-porous, hygienic surfaces resistant to bacterial buildup and compatible with repeated cleaning cycles. Use of certified materials and attention to 3D printing technology, nozzle type (preferably stainless steel over brass to avoid lead contamination), and surface finishing are key risk mitigation steps.

The mould component of the semi-automatic curry puff machine was fabricated using food-grade Polyethylene Terephthalate Glycol (PETG) filament. PETG was selected due to its superior chemical resistance, mechanical strength, and thermal stability compared to commonly used alternatives such as PLA and Nylon. While PLA is biodegradable and easy to print, its relatively low heat resistance and brittleness make it less suitable for repeated food-processing operations. Nylon, although mechanically robust, presents challenges related to moisture absorption and surface porosity, which may compromise hygienic performance in food-contact applications.

In contrast, food-grade PETG offers a balanced combination of durability, dimensional stability, and compliance with food-contact requirements when properly processed. Its lower shrinkage rate also improves print accuracy, enabling the production of mould geometries that support consistent crimping pressure and product uniformity.

To mitigate the inherent surface porosity associated with fused deposition modelling (FDM), the printed mould underwent mechanical sanding followed by sealing with a certified food-grade epoxy coating. This post-processing treatment created a non-porous barrier that reduces bacterial retention, enhances cleanability, and improves resistance to repeated washing cycles. Additionally, a stainless-steel nozzle was utilized during printing to minimize contamination risks often linked to brass nozzles.

Collectively, these measures ensured that the fabricated mould satisfied both functional and hygienic requirements for SME-scale food production environments. Figure 3 shows a printed curry puff mould using 3D printer.

Figure 3. Printed curry puff mould using 3D printer

3.2. CAD Design and Machine Configuration

The mechanical layout of the semi-automatic curry puff machine was developed using computer-aided design (CAD) software during the Design phase of the CDIO framework. The CAD model enabled visualization of component integration, spatial arrangement, and operational workflow prior to fabrication, thereby reducing design uncertainty and material waste.

The machine was configured to support a sequential production process consisting of dough placement, filling, mould-based forming, and automated crimping. Emphasis was placed on achieving a compact footprint suitable for SME facilities while maintaining structural rigidity and operator accessibility.

Engineering considerations incorporated into the design included:

- optimized mould alignment for uniform sealing pressure
- modular architecture to simplify maintenance and part replacement
- ergonomic height to reduce operator fatigue
- guarded mechanical elements to enhance user safety

The virtual model also facilitated early detection of potential mechanical interference and allowed iterative refinement before prototype construction, contributing to a more efficient implementation stage. Figure 4 shows the CAD design for semi-auto-curry puff machine

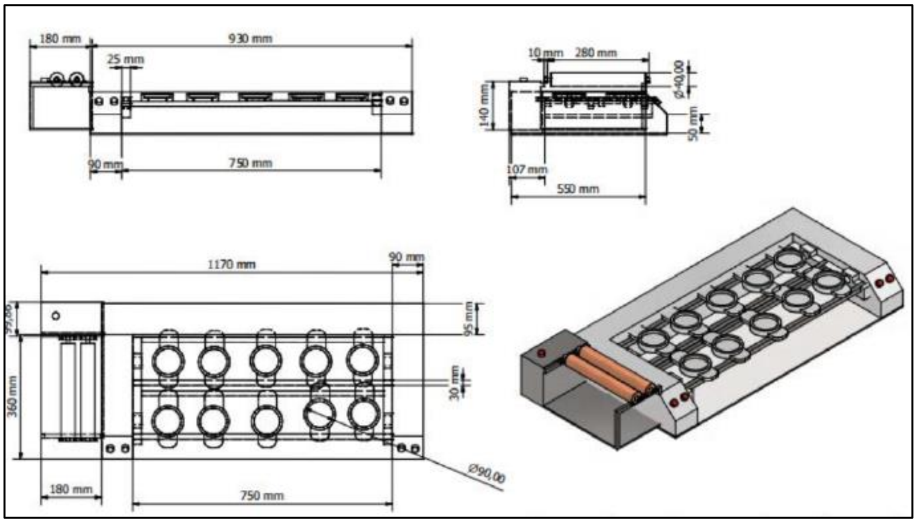

Figure 4. CAD design for semi-auto-curry puff machine

4. RESULTS

4.1. Operational Time Reduction

To ensure consistency across the experimental trials, 2 kg of dough was used for each test. Each production test was repeated five times to improve measurement reliability and minimize random error. The averaged results provide a stronger basis for evaluating machine performance and operational efficiency.

The findings clearly demonstrate that the Semi-Automatic Curry Puff Machine outperforms the traditional method in terms of production speed. For a batch of 10 curry puffs, the machine completed the process in 7.38 minutes, compared to 10.47 minutes using the manual technique, representing a 29.5% reduction in operational time. As production volume increased from 10 to 50 units, the machine consistently required less processing time, confirming its capability to sustain efficiency under higher workload conditions.

From a productivity perspective, the machine achieved an approximate production rate of up to 10 curry puffs per minute, indicating a substantial improvement in throughput. The traditional method, however, depends largely on the operator's manual skills, which introduces variability in shaping speed and product uniformity. This operator dependency may lead to fatigue during prolonged production, further reducing efficiency.

The results also highlight an important scalability advantage. While manual production time increases almost proportionally with batch size, the semi-automatic system demonstrates a more controlled and predictable time increment. This suggests that the machine is better suited for small and medium-sized enterprises (SMEs) seeking to expand production without significantly increasing labour requirements.

Statistically, the consistent time gap observed across all trials suggests a meaningful performance improvement rather than random variation. Although advanced statistical tests were not conducted, the repeated trials and stable trend strongly support the reliability of the findings.

Overall, the developed machine shows the potential to reduce operational time by approximately 30–50%, depending on batch size and operator handling. Beyond time savings, the system enhances production consistency, reduces physical workload, and improves process standardization. These advantages position the Semi-Automatic Curry Puff Machine as a practical and cost-effective technological intervention for modernizing traditional food production.

4.2. Optimization of 3D Printed Mould Surface and Resolution

Surface quality assessments highlighted the following findings:

FDM prints exhibited an average surface roughness (Ra) of approximately 12–15 µm, resulting in a porous surface prone to bacterial entrapment. After sanding and epoxy coating, Ra values decreased to below 2 µm, significantly improving cleanability.

SLA prints initially achieved lower Ra values (4–6 µm). Following post-curing and coating, Ra further decreased to around 1 µm. Despite superior finish, SLA resins remain costly and are less compatible with direct food contact. Repeated cleaning tests demonstrated that food-grade epoxy-coated moulds withstood at least 15–20 use cycles without significant surface degradation. In contrast, uncoated moulds displayed visible staining and oil absorption after only 3–5 cycles. Figure 5a shows a Traditional curry puff plastic mould and Figure 5b shows a 3D printer plastic mould

Figure 5a. Traditional curry puff plastic mould

Figure 5b. Traditional curry puff plastic mould

5. Conclusion

This study demonstrates that the structured application of CDIO principles, together with cost-effective 3D-printed moulds, can enable SMEs in the food sector to modernise production with affordable, efficient, and safe semi-automatic machinery. Iterative prototyping, coupled with direct user input and careful validation against ergonomic and food safety standards, resulted in a machine that dramatically improved productivity, hygiene, and product consistency for SME curry puff makers. Economic and sustainability analyses reveal that such solutions are both feasible and impactful for small-scale operations often left behind by conventional industrial automation.

The combination of modular, rapid, food-grade mould fabrication and mechanical semi-automation delivers clear competitive advantages for SMEs seeking to scale or diversify. The project's CDIO-driven approach is replicable for other food products and SME contexts, supporting wider digital transformation and sustainable growth in line with national and international goals. Ongoing advances in 3D printing materials and digital engineering promise further improvements in durability, safety, and adaptability; as such, SME leaders and policymakers should support wider dissemination and adoption of these methodologies.

The Semi-Automatic Curry Puff Machine was persuaded based on several key structural components, including a curry puff mould (12.5 cm × 11 cm), a wooden roller (28 cm diameter × 30 cm), and a stainless-steel shaft measuring 73 cm × 2.5 cm. The selection of stainless steel enhances corrosion resistance and food hygiene, while the roller mechanism supports uniform dough thickness, contributing to consistent product formation. These design considerations directly influence operational efficiency and production reliability. Operational testing revealed that the machine completes one production batch in 7.38 minutes. When extrapolated to an hourly basis, the system is capable of approximately 8.13 production cycles per hour (60 ÷ 7.38). Each cycle processes roughly 1.5 kg of potato filling with 1 kg of flour, resulting in an estimated hourly production capacity of 12.2 kg of curry puff material under continuous operation.

A critical performance indicator observed in this study is the reduction in processing time per batch. Compared to the traditional method, which required 10.47 minutes to produce a similar batch size, the semi-automatic system demonstrates a time reduction of approximately 29–30%. This improvement is significant because batch processing time directly determines production throughput. Shorter cycles enable more batches to be completed within the same operational window, thereby increasing total output without additional labour.

The reduction in batch duration substantially enhances manufacturing efficiency. For example, within one hour, the traditional method would complete approximately 5–6 batches, whereas the semi-automatic machine can exceed 8 batches, representing a notable improvement in operational performance. Moreover, reduced batch time contributes not only to higher productivity but also to improved workflow predictability. Manual production is often subject to human fatigue, inconsistent shaping speed, and ergonomic limitations, all of which introduce variability into the process. The semi-automatic mechanism minimizes these factors by standardizing key production steps, resulting in more stable cycle times and consistent product output. From an SME adoption perspective, this level of efficiency is particularly valuable. Many small-scale food producers face constraints related to workforce size, production time, and operational costs. By shortening the processing time per batch while simultaneously increasing hourly capacity, the developed machine supports scalable production without requiring proportional increases in manpower.

In conclusion, the data analysis confirms that the Semi-Automatic Curry Puff Machine delivers measurable improvements in manufacturing efficiency through significant batch time reduction and enhanced hourly throughput. The integration of mechanical assistance into a traditionally manual process demonstrates strong potential for modernizing small-scale food production. Consequently, the machine represents a practical and economically beneficial innovation for SMEs seeking to improve productivity, standardize operations, and remain competitive in an increasingly technology-driven food industry.

REFERENCES

[1] A. A. Al-Bakri et al., "Tensile and fracture behaviour of very thin 304 stainless steel sheet," Jurnal Teknologi. Available: https://journals.utm.my/jurnalteknologi/article/view/9146

[2] D. Drummer, S. Cifuentes-Cuéllar, and D. Rietzel, "Suitability of PLA/TCP for fused deposition modelling," Rapid Prototyping Journal, vol. 18, no. 6, pp. 500–507, 2012. Available: https://doi.org/10.1108/13552541211127204

[3] M. F. Fazdi and P.-W. Hsueh, "Parameter identification of a permanent magnet DC motor: A review," Electronics, vol. 12, no. 12, p. 2559, 2023. Available: https://www.mdpi.com/2079-9292/12/12/2559

[4] M. H. K. Mohamad Kamal and S. A. Sulaiman, "Design, analysis and fabrication of an automated shirt folder," UiTM Institutional Repository. Available: https://ir.uitm.edu.my/id/eprint/90463/

[5] RC Machinery, "Mesin Karipap Magic 10 / Machine Curry Puff Magic 10." Available: http://rcmesin.com/product/mesin-karipap-magic-10-machine-curry-puff-magic-10

[6] Y. Bi et al., "Research the landscape and trending topics on 3D food printing," Rapid Prototyping Journal, vol. 30, no. 2, pp. 145–160, 2024. Available: https://doi.org/10.1108/rpj-02-2024-0098

[7] CDIO Initiative, "CDIO Standards 3.0," 2021. Available: https://cdio.org

[8] J. Ng Kok Wah, "AI-powered 3D and 4D food printing: New ideas for making things more sustainable and unique," Food Reviews Around the World, 2025. Available: https://doi.org/10.1080/87559129.2025.2502438

[9] M. Rinshana et al., "Advances in 3D food printing technology: Innovation and applications," Food Science and Biotechnology, vol. 33, no. 1, pp. 12–25, 2024. Available: https://doi.org/10.1007/s10068-024-01779-7

[10] M. Sohel et al., "3D food printing: A comprehensive review and critical analysis," Food Engineering Reviews, vol. 17, no. 1, pp. 1–20, 2025. Available: https://doi.org/10.1007/s12393-025-09400-1

[11] L. Tan et al., "Automation in Southeast Asian food SMEs: Challenges and opportunities," Journal of Food Engineering, vol. 280, pp. 110–118, 2020.