

INTEGRATION OF TECHNOLOGY AND AUTOMATION: EFFICIENCY AND HALAL-COMPLIANCE IN BRUNEI BAKERIES

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ABSTRACT

Post COVID-19 era underscores the necessity for businesses to integrate technology to stay competitive while upholding ethical and cultural values. This study explores the convergence of tradition and innovation in Brunei's bakery industry, stressing the imperative of balancing operational excellence with stringent halal standards. The significance of workforce adaptation, inefficiencies in manual processes, and the importance of modernisation for domestic and global competitiveness were investigated using a qualitative research approach through purposive sampling and structured interviews to investigate technology's impact on efficiency and halal compliance in Brunei's bakery industry. Results highlight varied approaches among companies, with some embracing technology for efficiency gains while others prioritise traditional methods for halal verification. Challenges include inventory management and obtaining halal certification, addressed through advanced tracking systems and training programmes. In conclusion, the study emphasises the need for tailored solutions to meet consumer expectations while optimising bakery operations.

Keywords: *Integration of Technologies, Automation, Efficiency, Halal-Compliance*

1. Introduction

The bakery industry has experienced significant transformations due to the integration of technology and automation. These advancements have revolutionized production processes, quality control, and overall efficiency, offering a broader range of products and greater consistency in outcomes. One of the most significant changes brought by technology is the introduction of automated equipment. Automated systems, such as dough mixers, proofing machines, and ovens, have streamlined the production process, reduced manual labour and improved consistency. These systems can handle large volumes of dough and ensure uniformity in baking, leading to a higher-quality end product. Additionally, automated packaging systems have enhanced the efficiency of packing and distributing bakery products, reducing the risk of contamination and increasing product shelf life (Fernandez et al., 2023).

Technological advancements have ushered in a remarkable transformation within the realm of bakery operations, significantly enhancing efficiency, quality, and sustainability (Garcia & Thoben, 2015). Furthermore, sustainability has emerged as a central concern within bakery operations. Bakeries are increasingly adopting eco-friendly practices, encompassing waste reduction strategies, energy-efficient equipment, and responsible ingredient sourcing. By reducing waste and energy consumption and sourcing ingredients responsibly, bakeries not only minimise their environmental impact but also cater to consumer preferences for sustainable products.

The implementation of technology also has implications for compliance with halal standards in the Brunei bakery industry. Automated systems can ensure that ingredients and production processes meet halal requirements, reducing the risk of cross-contamination with non-halal products (Abidin & Perdana, 2020). This is particularly important in a market where halal compliance is a significant consumer concern. Technology can support rigorous tracking and certification processes, providing assurance to consumers about the halal status of bakery products (Shafii & Khadijah, 2012).

This research explores the integration of technologies and automation within the Brunei bakery industry, aiming to analyse its impact on operational efficiency and the maintenance of halal compliance. This research places a significant emphasis on the adaptation of the bakery workforce to these technological advancements. It underscores the importance of employee training and addresses potential resistance to automation, as the human element remains an integral part of the industry's success. By investigating these critical aspects, this study presents a compelling case study of how innovation can drive efficiency and halal compliance concurrently.

2. Materials and Methods

The methodology for this case study on the integration of technologies and automation within the Brunei bakery industry, focusing on efficiency and halal compliance with three research objectives, as follows:

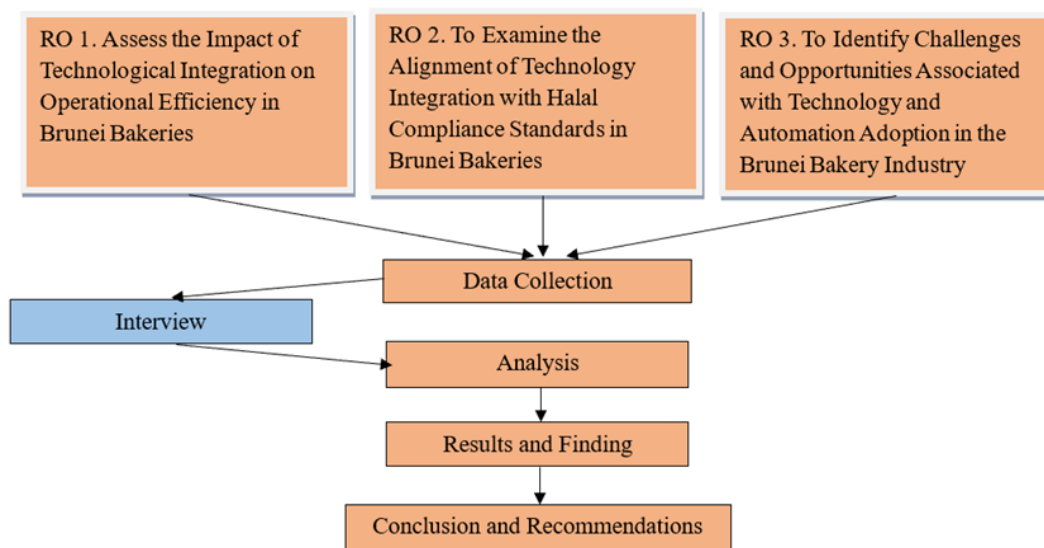


Figure 1: Research Design

2.1 Research Design

A qualitative research design is used to investigate the integration of technologies and automation in a specific bakery in Brunei. By focusing on qualitative methods, the research allows for a deeper exploration of the human experiences and contextual factors that quantitative methods might overlook. Interviews and open-ended questioning are used to capture the subjective experiences of bakery staff, managers, and other stakeholders.

2.2 Study Population and Sampling

A purposive sampling method is employed to ensure that the most relevant and representative cases are selected within the Brunei bakery industry. The case study selects specific bakeries based on their representation of the broader industry and the insights they can provide on technology adoption, efficiency, and halal compliance. Interviews are conducted with participants from four distinct bakery businesses, each representing a different segment of the industry:

- A bakery focusing on handcrafted pastries and cakes, catering to upscale events.
- A bakery known for trendy desserts appealing to a younger demographic.
- A bakery specialising in traditional baked goods, balancing traditional methods with modern technology.
- A bakery known for cakes and pastries with a strong emphasis on custom designs.

2.3 Research Instruments, Data Collection and Analysis

Structured interviews are the primary research method, using a predetermined set of questions and a standard format to ensure consistency in data collection. These questions are designed to explore the implementation of technology, its impact on efficiency, and the measures taken to ensure halal compliance within the selected bakeries. As shown in Figure 1, a systematic approach is used for data collection, with interviews conducted using a structured interview protocol. Participants are selected based on their roles in bakery management, involvement in technology adoption, and experience with halal compliance. Informed consent is obtained, and privacy and confidentiality are ensured throughout the process. Interviews are recorded through note-taking and, with consent, audio recordings. Thematic analysis is applied to identify patterns and insights, with cross-verification of findings to enhance rigour.

Data analysis involves transcriptions of recorded interviews and subsequent coding and categorisation to identify recurring themes related to technology adoption, operational efficiency, and halal compliance. The analysis evaluates the impact on production processes, resource utilisation, and overall workflow while examining measures taken to ensure halal compliance and the challenges faced. Triangulation is used to ensure reliability, comparing data across different sources and bakeries. This comprehensive analysis provides insights into the integration of technology, efficiency, and halal compliance in the Brunei bakery industry, offering practical recommendations for bakery operators and policymakers.

3. Results and Discussion

The study focuses on technology adoption to enhance efficiency and ensure halal compliance in the Bruneian bakery industry and finds common ground with previous studies that explore the benefits of automation and technology integration in the food industry. Earlier research typically highlights the potential for technology to streamline production processes, increase productivity, and improve product quality. This aligns with the Bruneian bakery industry's approach to using modern pastry rollers and label makers to boost efficiency and ensure consistent standards. However, the unique context of maintaining halal compliance

introduces additional layers of complexity not always covered in previous studies. While general research on bakery automation may emphasise operational efficiency, the focus on halal standards requires a more nuanced approach. This study's emphasis on real-time monitoring and traceability is crucial in this context, highlighting how technology can aid in ensuring compliance with religious and ethical requirements.

Furthermore, the study's emphasis on proactive solutions, such as training programmes and individualised learning processes, differs from earlier studies that often address technology adoption in broader terms without detailing how industries overcome challenges. This research's detailed exploration of overcoming obstacles demonstrates a problem-solving orientation and a strategic approach to integrating technology, suggesting a higher level of adaptation and resilience in the Bruneian bakery sector.

The challenges faced during technology implementation are met with solutions, including training programmes, continuous support and more individualised learning processes. This problem-solving orientation demonstrates a commitment to overcoming obstacles and ensuring the successful integration of technology into bakery operations. Identifying manual processes for automation and considering future technology integration showcases a forward-thinking approach. Technology adoption is strategically aligned with the industry's objectives of improving efficiency and maintaining high-quality standards. In the realm of halal compliance, technology is recognised as pivotal in ensuring transparency, accuracy, and adherence to halal standards. Challenges, such as verifying the halal status of products without recognised logos, underscore the ongoing efforts required to navigate the complexities of halal compliance in the bakery industry.

The responses collectively depict a resilient and adaptive bakery industry in Brunei. The industry leverages technology to overcome challenges, enhance operational efficiency, and meet the stringent standards of halal compliance. This narrative reflects a forward-thinking and solution-oriented approach within the Bruneian bakery sector. The four bakery companies were categorised into two groups: those with integrated technology and those without. The discussion unfolded through responses to ten questions, with five directed towards companies embracing technology and the other five towards those yet to adopt it.

Figure 2 provides a comprehensive overview of the quest for operational excellence through the thoughtful integration of technology in Brunei's bakery industry. This figure presents a thematic analysis extracted from the responses gathered. By carefully examining the insights provided by companies A, B, and C, the analysis summarises key themes, patterns, and observations that define how technology is embraced in bakery operations.

Figure 2 illuminates the detailed perspectives, obstacles, and opportunities faced by bakeries in Brunei. This integration aims to elevate operational efficiency while upholding the quality standards inherent in traditional baking methods. As such, Figure 2 acts as a valuable lens, offering a detailed exploration of the dynamic relationship between technology and bakery practices in Brunei.

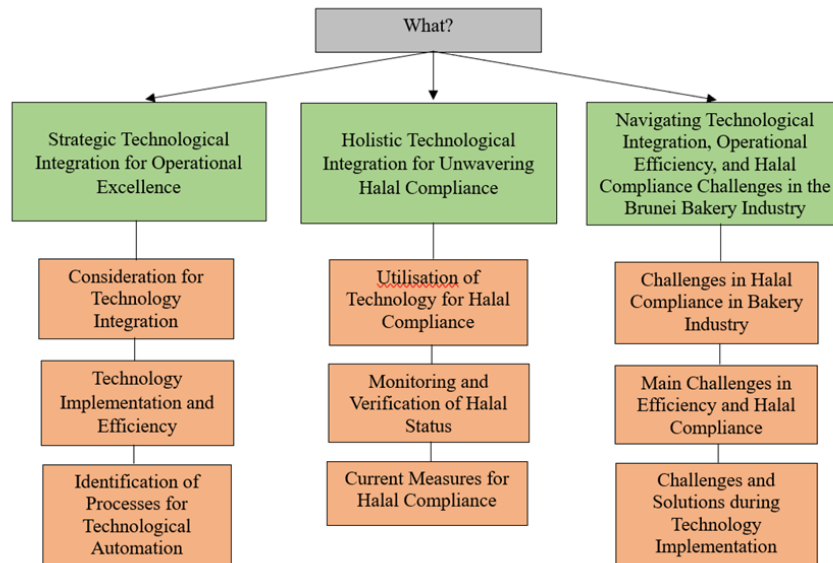


Figure 2: Thematic Analysis based on respondent's answers

3.1 Strategic Technological Integration for Operational Excellence

This section focuses on the strategic selection and implementation of technology to improve bakery operations in Brunei, particularly in terms of operational efficiency and addressing challenges while seizing opportunities.

3.1.1 Considerations for Technology Integration

Question and Extraction	
What specific technology/automation are you considering to integrate into your bakery operations?	<p>A: "We are exploring several options to enhance our bakery operations. Firstly, we plan to implement a modern pastry roller to increase efficiency in our pastry production. Additionally, we are considering the integration of label makers to automate and streamline the creation of package labels for our bakery products. These technologies will help us improve operational processes and maintain high-quality standards"</p> <p>B: "None at the moment"</p>

Source: Data Analysis

Different bakeries in Brunei consider various technologies for integration. Company A is exploring a modern pastry roller to enhance pastry production efficiency and label makers to streamline package labelling. This reflects a proactive approach toward improving operational processes while maintaining quality standards. It indicates a thoughtful strategy where technology serves to meet specific operational and quality-related goals. In contrast, Company B responded with "None at the moment," indicating no current consideration for specific technology. This doesn't suggest resistance to technology but rather reflects a measured approach, allowing for future exploration. This perspective acknowledges the importance of traditional methods while staying open to technological advancements when appropriate.

3.1.2 Technology Implementation and Efficiency

Question and Extraction	
Which specific technologies are implemented in your company and how it impacted the overall efficiency in the bakery operations?	<p>C: <i>“We’ve been using some machines in our kitchen, like a small dough maker, a round dough shaper, a big oven, and a chiller/freezer. Each machine has its own job, making our production better. The small dough maker mixes and prepares dough really well, making sure our product is always good. The round dough shaper shapes the dough just right, making things easier. The big oven bakes everything evenly, and the chiller/freezer keeps our products fresh. All these machines work together, making our kitchen run smoothly. They each do their part, making our work easier and our products always top-notch.”</i></p> <p>D: <i>“One technology we’ve implemented is using cookies printer. It speeds up the process of decorating the cookies design which usually took about 5min or more on 1pc cookie, but using the printer it took only less than a minute.”</i></p> <p>Source: Data Analysis</p>

In this section, bakeries describe the specific technologies implemented and their impact on operational efficiency. Company C highlights the use of various machines, including a small dough maker, a round dough shaper, a big oven, and a chiller/freezer. These technologies significantly improve kitchen operations, ensuring consistency, precision, and overall efficiency in the production process. The small dough maker is praised for its role in ensuring consistent dough preparation, while the round dough shaper improves precision in shaping dough, streamlining the workflow. The big oven is recognised for its even baking, which contributes to product quality, and the chiller/freezer plays a crucial role in maintaining freshness. The synergy among these machines demonstrates the instrumental role of technology in enhancing operational efficiency and quality. Company D implemented the cookies printer, dramatically reducing the time to decorate cookies from about five minutes to less than a minute. This technology speeds up production, reduces labour costs, and opens opportunities for increased output, illustrating how technology can transform operational efficiency.

3.1.3 Identification of Processes for Technological Automation

Question and Extraction	
What are the existing manual processes within the bakery operations that you believe could benefit from technological automation integration?	<p>A: <i>“Currently, our order-taking process involves a lot of manual entry and communication. We believe implementing technology for order management systems could greatly enhance the accuracy of orders, reduce errors, and improve communication between our customers and the bakery. Managing our stock levels and the requisition process is currently done manually. We see the potential for technology to play a crucial role in this area. When it comes to creating new products or recipes, we currently rely on manual calculations. Integrating technology for recipe management could significantly speed up this process, ensuring precise ingredient measurements and enhancing consistency in the creation of new bakery items. Our current process for creating package labels involves manual steps. Automating this task through technology could streamline the labeling process, ensuring compliance with regulatory requirements. In the production phase, we use manual pastry rollers and stampers.”</i></p> <p>B: <i>“Cake layering and coloring the batter so it would be consistent.”</i></p> <p>Source: Data Analysis</p>

Companies identify existing manual processes that could benefit from technological automation. Company A sees potential for technology in the order-taking process to improve accuracy, reduce errors, and enhance customer communication. Technology integration in stock management could also help streamline inventory tracking and requisition. Automating recipe management is proposed to ensure precise measurements and consistency, improving the quality of new bakery items. Additionally, automating package labeling could ensure regulatory compliance and reduce errors. Exploring automated pastry rollers and stampers could increase efficiency in production. Company B identifies cake layering and batter coloring as specific manual processes that could benefit from technological automation. This emphasis on these aspects indicates a focus on achieving consistency and precision in the baking process, suggesting an adaptive approach to improving operational efficiency. The bakery's interest in exploring technological solutions aligns with broader industry trends emphasizing innovation and operational optimisation.

3.2 Holistic Technological Integration for Unwavering Halal Compliance

This section explores the role of advanced technology in addressing challenges, monitoring, and verifying halal status in the Brunei bakery industry. It discusses how bakeries ensure compliance with halal standards and navigate the complexities of halal production and distribution.

3.2.1 Utilisation of Technology for Halal Compliance

Question and Extraction	
How were technology/automation utilised to ensure halal compliance within the process?	<p><i>C: "We decided to use automation in our processes to have better control over the ingredients we use, making sure they follow halal standards accurately. These machines help us keep a close eye on the entire production, ensuring that halal and non-halal items stay completely separate at every stage. This way, we can guarantee that our products meet the strict requirements of halal standards from start to finish."</i></p> <p><i>D: "To ensure halal compliance, I make sure that the ink used in the printer is edible and contains no non-halal ingredients. Before purchasing the ink, I inquire about its ingredients. Additionally, I ensure that all ingredients used in my cookies are halal, and the entire baking process is carried out in a clean environment."</i></p> <p style="text-align: center;">Source: Data Analysis</p>

Bakeries in Brunei use technology in different ways to maintain halal compliance. Company C employs automation to control ingredients, ensuring they meet halal standards. This automation provides precise monitoring throughout the production process, reducing the risk of human error and preventing cross-contamination between halal and non-halal items. The use of machines allows for detailed oversight, ensuring that each stage of production adheres to halal requirements. Company D, on the other hand, uses a more manual approach, emphasising the importance of clean environments and ensuring that all ingredients, including those used in ancillary processes like printing, are halal-compliant. The representative checks printer ink ingredients and ensures that the entire baking process is carried out in a manner that meets halal standards. These differing approaches to technology and automation reflect a common goal of ensuring halal compliance while demonstrating flexibility in implementation. Company C's use of automation offers precision and

efficiency, while Company D's hands-on approach emphasises careful monitoring and detailed checks.

3.2.2 Monitoring and Verification of Halal Status

Question and Extraction	
What steps were taken to monitor and verify the halal status of ingredients, processed and final product?	<p><i>C: "Our advanced technology allows us to keep a constant check on the ingredients in real-time. At every step of the production process, we use digital tracking to monitor and record all the details. We've set up a thorough system to confirm the halal status, ensuring complete transparency and compliance with halal standards. This comprehensive approach guarantees that we maintain a high level of accuracy and adherence to halal requirements throughout our production processes."</i></p> <p><i>D: "As mentioned earlier, I asked about the ink ingredient first before buying it. And also the whole ingredients for my cookies are halal and the whole process is clean. This includes verifying the halal status of ingredients, monitoring the production process, and ensuring the final product remains halal."</i></p> <p>Source: Data Analysis</p>

The use of technology plays a significant role in monitoring and verifying halal status within production processes. Company C utilises advanced digital tracking systems to monitor ingredients in real-time, ensuring complete transparency and compliance with halal standards. This continuous tracking allows the bakery to maintain a comprehensive overview of each step in the production process, reducing the risk of contamination and ensuring consistent adherence to halal guidelines. Company D relies on a more personal method of verification, with the representative emphasising the need for thorough checks and inquiries. This includes asking about ingredients in printer ink and ensuring that all components used in cookies are halal-compliant. The monitoring process extends to the entire production environment, maintaining cleanliness and strict adherence to halal principles. While Company C's approach focuses on technology for real-time tracking, Company D's method relies on manual oversight and rigorous checks, demonstrating diverse strategies for achieving the same goal of halal compliance.

3.2.3 Current Measures for Halal Compliance

Question and Extraction	
How is halal compliance currently ensured the production processes?	<p><i>A: "First, we avoid products that obviously use or contain alcohol and unknown animal sources. This proactive measure helps us in maintaining a halal environment during production. Secondly, we stay up to date with @halal.bn for announcements on products that may not be halal, such as pastry brushes, White Rabbit confectionary, and Tim Tam biscuits. This continuous monitoring ensures that we are aware of any updates or changes that may impact the halal compliance of our bakery products."</i></p> <p><i>B: "Part of halal requirements at least to have a Muslim helper and ingredients and equipment to be halal compliance. In our case our baking is process is all manual (except for a cake mixer for the dough) so all is done per halal requirement."</i></p> <p>Source: Data Analysis</p>

Different measures are taken to ensure halal compliance during production. Company A avoids products containing alcohol (ethanol) or unknown animal sources to maintain a halal environment. Additionally, the company stays updated with announcements from

@halal.bn, ensuring that products which may not be halal, such as certain confectioneries and biscuits, are not used. This proactive monitoring reflects the bakery's commitment to maintaining halal standards. Company B follows a manual approach, with most baking processes carried out manually, except for a cake mixer used for dough preparation. The company emphasises having a Muslim helper as part of its compliance with halal requirements, ensuring that the baking process is in line with Islamic principles. The careful selection of ingredients and equipment underscores the bakery's dedication to halal compliance, reinforcing the significance of manual processes in maintaining adherence to halal standards. Together, these approaches demonstrate the bakery industry's flexibility to meet halal compliance standards. Company A's proactive monitoring and avoidance of non-halal products, combined with Company B's emphasis on manual processes and a Muslim helper, reflect a holistic approach to ensuring halal compliance in the Brunei bakery industry.

3.3 Navigating Technological Integration, Operational Efficiency, and Halal Compliance Challenges in the Brunei Bakery Industry

This section explores the strategic considerations, challenges, and opportunities that arise from technology adoption in the Brunei bakery industry. It discusses the complexities of operational efficiency, halal compliance, and the unique issues faced by bakeries in this context.

3.3.1 Challenges in Halal Compliance in Bakery Industry

Question and Extraction	
Can you elaborate on the specific challenges faced by the bakery industry in ensuring halal compliance?	<p>C: "Ensuring that our products meet halal standards requires careful attention to every detail, starting from where we source our ingredients to the actual production process. One significant challenge is the risk of cross-contamination and ensuring traceability throughout the entire supply chain. However, our approach, heavily reliant on technology, has proven effective in overcoming these challenges. By implementing advanced tracking systems, we can closely monitor and control each step of the process, reducing the likelihood of cross-contamination and ensuring the traceability of our products."</p> <p>D: "I find it hard especially for homebased as halal only given to those with proper shop or place to do the baking. And it also takes so many processes before approval. e.g. by checking all the ingredients used even though it was bought in the local market which is obviously put in a halal section at the shop."</p> <p>Source: Data Analysis</p>

Company C highlights the risk of cross-contamination and the importance of ingredient traceability. With numerous ingredients in use, the potential for cross-contamination requires meticulous attention. To address this, Company C employs advanced tracking systems to monitor production, reducing the risk of cross-contamination and ensuring halal integrity. The company's technology-driven approach enables a higher level of control, reinforcing compliance with strict halal standards. Conversely, Company D, a home-based business, underscores the difficulties in obtaining halal certification. The need for a dedicated commercial baking space is a barrier, particularly for smaller operations. Additionally, the lengthy and intricate approval process, which involves detailed inspections and ingredient verification, makes it challenging for home-based bakeries to obtain certification. Despite buying ingredients from local markets with dedicated halal sections, Company D finds that even these require thorough inspection, adding to the complexity of the certification process.

These differing perspectives illustrate the varied challenges faced by bakeries in maintaining halal compliance. Company C relies on technology to manage cross-contamination, while Company D navigates the complexities of certification for smaller operations.

3.3.2 Main Challenges in Efficiency and Halal Compliance

Question and Extraction	
What are the main challenges faced regarding efficiency and halal compliance?	<p><i>A: "Firstly, keeping stocks at par level is an ongoing challenge, requiring careful monitoring and management to prevent shortages or excess inventory. Secondly, the fluctuating availability and prices of raw materials since COVID-19. It is affecting both the cost and availability of essential ingredients, influencing our production efficiency. Another challenge is related to confirming the halal status of products that lack recognised halal logos. To ensure compliance, we often find ourselves in a position where we need to spend our own funds to have government bodies confirm the halal status of such products. Lastly, most packaging suppliers, for example, Wan Sing Trading, do not have halal certificates for their products."</i></p> <p><i>B: "None with machinery at the moment just ingredients as some ingredients are not available in the country and if we were to use halal ingredients that are not on Brunei halal list the process of getting it accredited is hard."</i></p> <p>Source: Data Analysis</p>

Company A identifies inventory management and raw material availability as ongoing challenges. Keeping stock levels balanced is crucial to avoid production disruptions, but fluctuating raw material prices and availability, especially post-COVID-19, impact efficiency. Additionally, confirming the halal status of products without recognised logos can be costly, requiring the bakery to spend its own funds for government verification. The lack of halal-certified packaging suppliers adds further complexity to compliance efforts. Company B, focusing on sourcing halal-compliant ingredients, notes that some required components are not readily available in Brunei, creating a challenge. When using ingredients not on the Brunei halal list, the process of obtaining certification is complex, requiring extensive effort and time. This underscores the difficulty in sourcing halal-compliant ingredients and the hurdles involved in ensuring compliance with halal standards. These challenges highlight the range of issues faced by bakeries in the Brunei industry. Company A emphasises inventory and raw material management, while Company B focuses on the complexities of sourcing halal-compliant ingredients.

3.3.3 Challenges and Solutions during Technology Implementation

Question and Extraction	
What were the initial challenges faced during the implementation of these technologies and how were they overcome?	<p><i>C: "When we introduced the new machines, our team faced some challenges because they were unfamiliar with how to use them. However, we tackled this by organising training programmes to teach everyone how to operate the machinery effectively. Alongside that, we provided continuous support, answering questions and addressing concerns. This combination of training and ongoing assistance allowed our staff to become proficient in using the new technologies, and we seamlessly incorporated them into our daily operations."</i></p> <p><i>D: "Well, since it's new, it took a while for me to understand how to use the software and also calibrating it. Even until now I'm still learning how to use it. Through experiment and also asking questions to the company providing the machine."</i></p> <p>Source: Data Analysis</p>

Company C describes the difficulty faced by staff when learning to use new machinery. To address this, the company organised training programmes to educate employees on operating the equipment. Continuous support was also provided, allowing staff to ask questions and resolve issues as they arose. This combination of training and support helped the team become proficient with the new technology, enabling a smooth transition in daily operations. Company D discusses the learning curve associated with new technology, particularly the cookies printer. The representative mentions that it took time to understand the software and calibration process, requiring experimentation and guidance from the technology provider. This hands-on approach, coupled with direct support from the machine's supplier, helped overcome initial challenges. These approaches illustrate the different methods bakeries use to address challenges during technology implementation. Company C adopts structured training and support, while Company D emphasises individual learning and experimentation. This flexibility in handling new technology reflects the diverse learning styles and organisational needs within the Brunei bakery industry.

3.4 Cross Synthesis

In the Brunei bakery industry, strategic technological integration is critical for enhancing operational efficiency and addressing various challenges while seizing opportunities. For instance, Company A is considering the integration of a modern pastry roller and label makers to improve production efficiency and streamline packaging processes. This approach is proactive and targets specific operational goals. Conversely, Company B currently has no plans for technological integration, reflecting a measured stance that balances tradition with potential future advancements. Implementing technologies such as dough makers, dough shapers, and ovens, as seen in Company C, has significantly improved operational efficiency by ensuring consistency and precision. Additionally, Company D's use of a cookies printer has dramatically reduced decorating time, illustrating the transformative impact of technology on production processes. Identifying areas for automation, such as order management, stock levels, and recipe management, further highlights opportunities for improving accuracy and reducing errors. Ensuring halal compliance presents another layer of complexity, where companies like C and D adopt different strategies to maintain stringent standards. Company C employs automation for ingredient control and monitoring, while Company D emphasizes manual checks and clean environments. Despite the challenges, including inventory management and sourcing halal-compliant ingredients, the implementation of training programs and ongoing support, as demonstrated by Company C, and hands-on experimentation, as seen in Company D, highlight the adaptability and commitment of bakeries in Brunei to achieving operational excellence through strategic technological integration.

4. Conclusion

The integration of technologies and automation into the bakery industry of Brunei, with a particular focus on ensuring halal compliance, represents a transformative journey that holds significant promise and potential. This case study has illuminated various implications of adopting cutting-edge technological solutions within the context of Brunei's halal-driven bakery sector. Throughout this investigation, it has become evident that the bakery industry in Brunei is at the forefront of leveraging technology to enhance operational efficiency while upholding the stringent requirements of halal standards. The challenges faced in this journey,

from the initial investment costs to workforce adaptation and regulatory compliance, have been met with strategic planning and a commitment to excellence. These challenges have been countered with tangible benefits, which include cost reduction, improved product consistency, and an enhanced ability to respond swiftly to market demands. Technology and automation have proven to be key drivers in this transformation. It not only lowers labour costs but also minimises the risk of product defects and recalls, optimising resource utilisation.

Furthermore, it ensures the uniform quality of bakery products, leading to higher customer satisfaction and brand loyalty. The ability to accelerate production and delivery times, coupled with the agility to adapt to changing market dynamics, has bolstered the competitiveness of the bakery industry in Brunei. However, this journey is not without its challenges, and the path forward requires continued vigilance. The evolving landscape of halal standards necessitates a proactive approach to regulatory compliance and the ongoing alignment of technology with halal requirements. Workforce adaptation remains a vital aspect, demanding investments in training and efforts to overcome employee resistance to automation. Last but not least, the integration of technologies and automation in the bakery industry of Brunei stands as a testament to the industry's commitment to excellence, efficiency, and halal integrity.

This case study has provided valuable insights into the challenges and opportunities encountered along the way, providing guidance and inspiration for bakery businesses seeking to embark on a similar transformative journey. As the industry continues to evolve, embracing innovation while preserving halal compliance remains central to its sustained success and growth. However, there is a need for further studies to explore several key areas. Firstly, examining the long-term effects of technology and automation on employment within the bakery industry can offer insights into workforce trends and skills development. Secondly, future studies could investigate the broader impact of technology on halal compliance, focusing on the supply chain and ingredient sourcing to understand how technology affects transparency and traceability.

Additionally, research could delve into the environmental impact of technology adoption, exploring sustainability practices and resource utilisation within the industry. Understanding how technology affects the industry's carbon footprint could guide future sustainable practices. Lastly, exploring consumer perspectives and expectations in response to technology integration could offer valuable insights into market trends and customer satisfaction. As the bakery industry in Brunei continues to embrace technology, addressing these areas through further studies can ensure a holistic approach to the ongoing transformation, balancing efficiency, halal compliance, and sustainable practices for the industry's continued success.

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