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Transforming Agro-Food Smes In Malaysia Through Digital Innovation And Smart Technologies For Sustainable Competitiveness

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Abstract: *The adoption of digital transformation in agro-food small and medium enterprises (SMEs) has emerged as a critical strategy to enhance productivity, market competitiveness, and sustainability. However, the adoption rate remains low due to financial constraints, limited digital literacy, inadequate infrastructure, and resistance to change. This paper presents a conceptual framework for understanding the factors influencing digital transformation in agro-food SMEs in Malaysia. By integrating theoretical models such as the Technology Acceptance Model (TAM) and the Diffusion of Innovation (DOI) theory, this study highlights the drivers, barriers, and strategic enablers of digital adoption. The findings suggest that targeted financial support, capacity-building programs, regulatory improvements, and digital infrastructure enhancement are essential for accelerating digitalization in the agro-food sector. Additionally, government initiatives and industry collaborations play a pivotal role in fostering an ecosystem conducive to technological adoption. This study provides valuable insights for policymakers, business owners, and researchers in developing strategies to facilitate digital transformation, ensuring long-term sustainability and competitiveness in the agro-food industry.*

Keywords: *Digital transformation, agro-food SMEs, technology adoption, e-commerce, blockchain.*

1. INTRODUCTION

The agro-food sector is a crucial pillar of Malaysia's economy, contributing significantly to food security, employment generation, and economic growth (Department of Statistics Malaysia, 2021). Small and medium enterprises (SMEs) dominate this sector, playing a vital role in ensuring the continuous supply of agricultural products, processed food, and value-added goods for both domestic consumption and international trade (Mohd et al., 2022). However, agro-food SMEs face multiple challenges, including outdated agricultural methods, inefficient supply chain processes, rising operational costs, and increasing competition from global markets (Ali et al., 2021). To address these challenges, strategic interventions are necessary, particularly through the adoption of digital transformation to enhance productivity, sustainability, and competitiveness.

Digital transformation has been recognized as a key enabler of business efficiency and sustainability across industries (Westerman et al., 2019). It entails the integration of advanced technologies such as artificial intelligence (AI), big data analytics, blockchain, the Internet of Things (IoT), and cloud computing into various business operations to drive innovation, improve productivity, and optimize supply chain management (Schroeder et al., 2020). In the agro-food sector, these technologies present transformative opportunities by modernizing farming practices, enhancing supply chain transparency, and improving

market accessibility through digital platforms (Sundmaeker et al., 2022). Despite these advantages, the adoption rate of digital technologies among agro-food SMEs in Malaysia remains low (Rahman et al., 2023). This is primarily due to financial limitations, digital literacy gaps, inadequate infrastructure, and resistance to change (Aziz et al., 2021).

1.1 The Significance of Digital Transformation in Agro-Food SMEs

The implementation of digital technologies in agro-food SMEs offers multiple benefits, including increased efficiency, market competitiveness, and environmental sustainability (Treiblmaier & Beck, 2021). Empirical studies have demonstrated that precision agriculture, AI-powered data analytics, and automated irrigation systems significantly enhance resource management, reduce production costs, and improve agricultural yields (Balafoutis et al., 2017). Additionally, blockchain technology and IoT-based tracking systems improve supply chain transparency, traceability, and operational efficiency, ensuring the delivery of high-quality food products to consumers (Tian, 2017). These digital solutions are crucial in tackling food security challenges and enhancing the resilience of agro-food supply chains (Dabbous & Tarhini, 2021).

The COVID-19 pandemic further highlighted the importance of digital transformation, as traditional market access channels faced severe disruptions (Aldaco et al., 2020). Many SMEs had to shift their operations to e-commerce platforms and digital marketing strategies to sustain their businesses (Sharma et al., 2022). Digital transformation enables agro-food SMEs to engage in direct-to-consumer sales, expand their market reach beyond geographical constraints, and establish robust business continuity plans (He et al., 2021). This shift is critical in ensuring the long-term adaptability and sustainability of agro-food enterprises in an increasingly digitalized global economy (Das et al., 2022).

1.2 Challenges to Digital Adoption in Agro-Food SMEs

Despite the clear benefits, several barriers hinder the widespread adoption of digital technologies among agro-food SMEs in Malaysia (Ismail et al., 2022). One of the primary challenges is financial constraints. Many SMEs operate on limited budgets, making it difficult to allocate resources for digital investments (Nordin et al., 2021). The high costs associated with technology implementation, system maintenance, and employee training further exacerbate financial burdens for small enterprises (Zainal et al., 2022).

Another major challenge is the lack of digital literacy among SME owners and employees (Kariyapperuma et al., 2021). A significant proportion of agro-food businesses still rely on conventional methods and have limited exposure to modern digital tools and platforms (Ali & Hossain, 2023). The absence of structured digital training programs and support mechanisms contributes to the reluctance in adopting digital transformation initiatives (Rahim et al., 2022). Moreover, inadequate digital infrastructure, particularly in rural areas where many agro-food SMEs operate, further hinders technological progress (Kumar et al., 2023). Limited internet connectivity and the lack of access to digital service providers create substantial barriers to digital adoption (Lal et al., 2022).

Resistance to change also plays a significant role in preventing digital adoption among agro-food SMEs (Wijethilake, 2021). Many business owners perceive digital technologies as complex, costly, and unnecessary, resulting in reluctance to integrate modern solutions (Santos et al., 2023). Concerns about data security, privacy risks, and trust in digital platforms further contribute to this hesitancy (Bai et al., 2022). Overcoming these challenges requires targeted policy interventions, capacity-building programs, and significant investments in digital infrastructure (Chen et al., 2023).

1.3 Government Policies and Support for Digital Transformation

Acknowledging the strategic significance of digital transformation in the agro-food sector, the Malaysian government has introduced various policies and programs to facilitate SME digitalization (Malaysian Digital Economy Corporation, 2022). Key initiatives such as the National Agro-Food Policy, Malaysia Digital Economy Blueprint, and the National Fourth Industrial Revolution Policy offer financial incentives, digital training programs, and infrastructure support to promote technology adoption among SMEs (Ministry of Agriculture and Food Industries, 2022). These government-led efforts aim to bridge the digital divide, enhance technological inclusivity, and boost the competitiveness of Malaysia's agro-food sector (Chandran et al., 2023).

Moreover, government agencies collaborate with industry stakeholders to provide financial grants, technology subsidies, and capacity-building programs for SMEs (Sulaiman et al., 2022). However, the effectiveness of these initiatives remains debatable, as many SMEs continue to encounter challenges in accessing funding and technical support (Rahman et al., 2022). A more integrated approach involving stronger public-private partnerships and localized digital adoption strategies is required to address these barriers effectively (Ahmad et al., 2023).

1.4 Theoretical Models Explaining Digital Transformation Adoption

Several theoretical frameworks offer insights into the adoption of digital transformation in agro-food SMEs. The Technology Acceptance Model (TAM) posits that perceived ease of use and perceived usefulness are key factors influencing technology adoption (Davis, 1989). This model provides a foundational understanding of how SME owners assess digital tools and the factors affecting their willingness to embrace technological advancements (Venkatesh & Davis, 2000).

The Diffusion of Innovation (DOI) theory explains the process through which new technologies are disseminated and adopted within industries, identifying five key stages: knowledge, persuasion, decision, implementation, and confirmation (Rogers, 2003). Understanding these adoption stages helps policymakers design targeted interventions to facilitate SMEs in integrating digital solutions into their business operations (Kapoor et al., 2021).

The Unified Theory of Acceptance and Use of Technology (UTAUT) extends the TAM framework by incorporating additional factors such as performance expectancy, effort expectancy, social influence, and facilitating conditions (Venkatesh et al., 2003). By synthesizing these theoretical perspectives, this study develops a conceptual framework for analyzing the drivers, barriers, and strategic approaches influencing digital transformation adoption among agro-food SMEs in Malaysia (Chong et al., 2022).

2. LITERATURE REVIEW

Digital transformation has emerged as a critical driver of innovation and efficiency across various industries, including the agro-food sector. The integration of technologies such as artificial intelligence (AI), blockchain, the Internet of Things (IoT), and big data analytics has the potential to modernize agricultural practices, optimize supply chains, and enhance market access for agro-food small and medium enterprises (SMEs). Despite the promising benefits, the adoption of digital transformation among Malaysian agro-food SMEs remains slow due to various structural, financial, and technological challenges. This literature review critically examines existing research on digital transformation in the agro-food sector, focusing on its role, benefits, barriers, government policies, and theoretical models that explain adoption patterns among SMEs.

2.1 Digital Transformation in the Agro-Food Sector

Digital transformation in the agro-food sector refers to the application of digital technologies to improve operational efficiency, sustainability, and market competitiveness (Treiblmaier & Beck, 2021). Emerging technologies such as AI, blockchain, and IoT are increasingly being implemented to enhance productivity and streamline agricultural supply chains (Balafoutis et al., 2017). These advancements enable real-time data monitoring, optimize resource allocation, and improve decision-making (Tian, 2017). Research highlights that AI-driven predictive analytics and IoT-based smart farming contribute to higher yields and better environmental sustainability (Dabbous & Tarhini, 2021). In addition, the use of cloud computing allows seamless integration of farm management data, supporting more efficient agricultural production (Boehlje, 2020).

2.2 The Role of SMEs in the Agro-Food Industry

SMEs play a crucial role in the agro-food industry by connecting producers and consumers, supporting local economies, and ensuring food security (Sharma et al., 2022). These enterprises are involved in value addition, food processing, and distribution, contributing significantly to national and global food supply chains (He et al., 2021). However, financial limitations and restricted access to advanced technologies remain significant challenges for SMEs (Das et al., 2022). Studies suggest that digitalization can help SMEs enhance operational efficiency, reduce costs, and expand market access (Ismail et al., 2022). Moreover, the integration of digital tools such as precision farming, e-commerce platforms, and automated logistics management improves productivity and strengthens SMEs' position in competitive markets (Ali & Hossain, 2023).

2.3 Benefits of Digital Transformation for Agro-Food SMEs

The adoption of digital technologies presents numerous advantages for agro-food SMEs, including improved efficiency, reduced operational costs, and enhanced market competitiveness (Nordin et al., 2021). Digital supply chain solutions, such as blockchain and IoT-enabled tracking systems, increase transparency and traceability in food production and distribution (Zainal et al., 2022). E-commerce platforms and digital marketing tools allow SMEs to expand their customer reach and boost revenue streams (Ali & Hossain, 2023). Moreover, precision agriculture techniques, such as remote sensing and automated irrigation, improve resource management and productivity (Rahim et al., 2022). The ability to leverage digital solutions for inventory tracking and logistics optimization further enhances SME resilience, particularly in times of market disruptions, such as during the COVID-19 pandemic (Dutta et al., 2021).

2.4 Barriers to Digital Adoption in Agro-Food SMEs

Despite the potential benefits, agro-food SMEs face multiple barriers to digital adoption. Financial constraints are among the most significant challenges, as many SMEs operate on limited budgets, making it difficult to invest in advanced technologies (Lal et al., 2022). Additionally, a lack of digital literacy and technical expertise among business owners and employees poses a significant obstacle to the adoption of new digital tools (Wijethilake, 2021). Research also suggests that inadequate digital infrastructure, particularly in rural areas, restricts the expansion of digital transformation initiatives (Santos et al., 2023). Resistance to change and concerns regarding data security and privacy further hinder SME owners from fully embracing digital transformation (Bai et al., 2022). Additionally, technological fragmentation and interoperability issues among different digital platforms create integration challenges, discouraging SMEs from fully adopting digital solutions (Zhu & Lin, 2022).

2.5 Government Initiatives and Policies Supporting Digital Transformation

To facilitate digital adoption among agro-food SMEs, the Malaysian government has introduced several policies and programs aimed at supporting digital transformation (Malaysian Digital Economy Corporation, 2022). The National Agro-Food Policy, Malaysia Digital Economy Blueprint, and the National Fourth Industrial Revolution Policy are among the strategic frameworks designed to promote digital technology adoption through financial incentives, training programs, and infrastructure development (Ministry of Agriculture and Food Industries, 2022). Collaborative efforts between government agencies and industry stakeholders provide financial grants, digital literacy programs, and advisory services to SMEs (Chandran et al., 2023). However, challenges in accessing these support mechanisms remain a concern, necessitating enhanced public-private partnerships and localized digital adoption strategies (Sulaiman et al., 2022). More efforts are required to ensure that funding programs are easily accessible to rural SMEs and that training initiatives effectively bridge knowledge gaps in digital literacy (Mustapha & Goh, 2023).

2.6 Theoretical Models Explaining Digital Adoption in Agro-Food SMEs

Several theoretical frameworks have been developed to explain the adoption of digital technologies in agro-food SMEs. The Technology Acceptance Model (TAM) suggests that perceived ease of use and perceived usefulness influence the decision to adopt new technologies (Davis, 1989). This model provides insights into how SME owners evaluate digital tools and their likelihood of adoption (Venkatesh & Davis, 2000). The Diffusion of Innovation (DOI) theory outlines the process by which new technologies are integrated into industries, identifying five stages of adoption: knowledge, persuasion, decision, implementation, and confirmation (Rogers, 2003). The Unified Theory of Acceptance and Use of Technology (UTAUT) expands on these models by incorporating performance expectancy, effort expectancy, social influence, and facilitating conditions as determinants of technology adoption (Venkatesh et al., 2003). Understanding these theoretical perspectives aids in designing targeted interventions to enhance digital transformation in agro-food SMEs (Chong et al., 2022). The Resource-Based View (RBV) framework also plays a crucial role in explaining digital adoption, emphasizing that firms must develop unique technological capabilities to achieve a competitive advantage (Barney, 1991).

By examining these key themes, the literature review underscores the significance of digital transformation in improving the efficiency and competitiveness of agro-food SMEs while also identifying challenges and policy interventions necessary for accelerating digital adoption in Malaysia's agro-food sector. Furthermore, the discussion highlights the importance of digital infrastructure, knowledge transfer, and institutional support in fostering sustainable digital transformation among SMEs.

3. ISSUESS IN THE ADOPTION OF DIGITAL TRANSFORMATION IN AGRO-FOOD SMES

The adoption of digital transformation in agro-food small and medium enterprises (SMEs) in Malaysia presents a myriad of challenges that hinder its widespread implementation. While digital technologies offer immense benefits, such as improved efficiency, cost reduction, and enhanced market access, several obstacles prevent SMEs from fully embracing these advancements. These challenges stem from financial constraints, inadequate digital infrastructure, lack of digital literacy, technological barriers, regulatory hurdles, and socio-cultural resistance. Understanding these issues is critical for policymakers, industry stakeholders, and SMEs to develop effective strategies that facilitate digital adoption and foster long-term sustainability.

3.1 Financial Constraints

One of the most significant barriers to digital transformation in agro-food SMEs is financial limitation. Many SMEs operate on tight budgets and struggle to allocate funds for investing in advanced digital technologies (Lal et al., 2022). The high costs associated with purchasing software, hardware, and digital infrastructure, as well as ongoing maintenance expenses, pose significant challenges for small enterprises (Sulaiman et al., 2022). Additionally, limited access to financial support mechanisms, such as government grants, bank loans, and venture capital, further restricts the ability of SMEs to invest in digital solutions (Wijethilake, 2021). Without adequate financial resources, SMEs are unable to adopt and integrate advanced technologies that could enhance their productivity and competitiveness.

3.2 Inadequate Digital Infrastructure

The availability and quality of digital infrastructure play a crucial role in enabling digital transformation. However, in Malaysia, there exists a digital divide, particularly between urban and rural areas (Santos et al., 2023). Many agro-food SMEs are located in rural regions where broadband connectivity is limited, power supply is inconsistent, and access to digital service providers is restricted (Rahim et al., 2022). These infrastructural limitations prevent SMEs from utilizing digital tools effectively, reducing their ability to compete in the modern digital economy. Bridging this gap requires strategic investments in digital infrastructure development to ensure equitable access to technology across all regions.

3.3 Lack of Digital Literacy and Technical Skills

A significant challenge faced by agro-food SMEs is the lack of digital literacy among business owners and employees. Many SME operators have minimal exposure to modern digital tools and platforms, leading to hesitancy in adopting new technologies (Sharma et al., 2022). The absence of adequate training and capacity-building programs further exacerbates this issue, making it difficult for SMEs to transition from traditional methods to digital solutions (Chong et al., 2022). Without proper digital literacy, SMEs struggle to maximize the benefits of digital transformation, limiting their ability to leverage data-driven decision-making and automation to improve efficiency.

3.4 Technological Barriers and Integration Challenges

Implementing digital technologies requires a seamless integration of various systems, including enterprise resource planning (ERP), digital supply chain management, and customer relationship management (CRM) tools. However, many agro-food SMEs face significant technological barriers due to outdated legacy systems, lack of interoperability between digital platforms, and insufficient technical support (Ali & Hossain, 2023). The complexity of integrating new technologies with existing operational frameworks further discourages SMEs from adopting digital solutions (Nordin et al., 2021). Addressing these challenges necessitates the development of user-friendly and cost-effective digital tools tailored to the needs of agro-food SMEs.

3.5 Regulatory and Policy-Related Challenges

Regulatory and policy-related challenges also hinder the digital transformation of agro-food SMEs in Malaysia. Compliance with digital regulations, such as data protection laws, cybersecurity requirements, and e-commerce policies, can be overwhelming for small enterprises with limited resources (Bai et al., 2022). Additionally, inconsistencies in regulatory frameworks and bureaucratic red tape create obstacles for SMEs seeking to adopt digital technologies (Chandran et al., 2023). Strengthening regulatory frameworks, streamlining administrative processes, and providing clearer guidelines on digital adoption can help mitigate these challenges and encourage more SMEs to embrace digital transformation.

3.6 Socio-Cultural Resistance to Change

Cultural resistance and skepticism toward digital technologies remain significant obstacles in the agro-food sector. Many SME owners and employees perceive digital transformation as a complex and unnecessary shift, leading to reluctance in adopting new technologies (Treiblmaier & Beck, 2021). Concerns about data security, privacy, and trust in digital platforms further contribute to this resistance (Dabbous & Tarhini, 2021). Additionally, the generational gap in technology adoption presents challenges, as older business owners may prefer traditional methods over digital solutions (Tian, 2017). Overcoming socio-cultural barriers requires targeted awareness campaigns, educational initiatives, and incentives that promote the benefits of digital adoption.

3.7 Cybersecurity Risks and Data Protection Issues

The increasing reliance on digital technologies exposes SMEs to cybersecurity risks and data protection challenges. Many agro-food SMEs lack the expertise and resources to implement robust cybersecurity measures, making them vulnerable to cyber threats, data breaches, and hacking attempts (Zainal et al., 2022). Additionally, concerns about intellectual property theft and unauthorized access to sensitive business information deter SMEs from fully engaging in digital transformation (Das et al., 2022). Strengthening cybersecurity frameworks, offering cybersecurity training, and implementing affordable security solutions can help mitigate these risks and build trust in digital adoption.

3.8 Limited Access to Digital Markets and E-Commerce Platforms

While digital transformation provides opportunities for SMEs to expand their market reach, many agro-food businesses face challenges in accessing digital markets and e-commerce platforms. High platform fees, intense competition, and the need for advanced digital marketing skills pose barriers for SMEs looking to establish an online presence (Ismail et al., 2022). Additionally, the dominance of large-scale agribusinesses in digital marketplaces makes it difficult for smaller enterprises to compete effectively (He et al., 2021). Facilitating SME participation in digital marketplaces through training, subsidies, and partnerships with e-commerce platforms can enhance their competitiveness and market penetration.

3.9 Uncertain Return on Investment (ROI)

Many SMEs hesitate to invest in digital technologies due to concerns about uncertain returns on investment (Nordin et al., 2021). The cost of implementing digital solutions can be substantial, and the benefits may not be immediately tangible, leading to skepticism among SME owners (Ali & Hossain, 2023). Addressing this issue requires comprehensive case studies, success stories, and financial modeling that demonstrate the long-term economic benefits of digital transformation for agro-food SMEs.

Addressing the challenges associated with digital transformation in agro-food SMEs requires a multi-faceted approach that includes financial support, improved digital infrastructure, capacity-building initiatives, regulatory reforms, and cultural shifts. By mitigating these barriers, SMEs can leverage digital technologies to enhance productivity, sustainability, and market competitiveness, ultimately contributing to the growth of Malaysia's agro-food sector. Future research should focus on developing targeted strategies and policy interventions that address these challenges effectively, ensuring that agro-food SMEs can fully benefit from digital transformation in the evolving digital economy.

4. DISCUSSION

The adoption of digital transformation in agro-food small and medium enterprises (SMEs) is essential for ensuring competitiveness, efficiency, and sustainability in Malaysia's agricultural sector. While

digitalization offers numerous benefits, including improved resource management, enhanced supply chain transparency, and better market accessibility, several challenges hinder its widespread adoption. These challenges, or issues, have been identified in previous sections and include financial constraints, digital literacy gaps, infrastructure limitations, cybersecurity risks, and regulatory barriers. This discussion section critically examines these issues, exploring their implications and potential solutions based on existing literature and empirical findings.

4.1 Financial Constraints and Investment Challenges

One of the most significant barriers to digital adoption in agro-food SMEs is the financial burden associated with acquiring and implementing digital technologies (Ali & Hossain, 2023). Many small enterprises operate on limited budgets and lack the necessary capital to invest in expensive digital solutions, such as Internet of Things (IoT) sensors, blockchain-based supply chain systems, and AI-driven analytics (Nordin et al., 2021). The high costs of acquiring software, maintaining digital infrastructure, and providing staff training pose considerable challenges for SMEs (Santos et al., 2023). Furthermore, the return on investment (ROI) for digitalization is often uncertain, which discourages SME owners from allocating resources toward technology adoption (Tian, 2017).

To address these financial constraints, governments and financial institutions must introduce targeted support mechanisms such as grants, low-interest loans, and subsidies for agro-food SMEs (Rahim et al., 2022). Public-private partnerships can also play a crucial role in reducing costs by providing affordable technology solutions and shared digital resources (Dabbous & Tarhini, 2021). Moreover, innovative financing approaches, such as microfinance and digital crowdfunding platforms, can enable SMEs to raise funds for digital transformation without relying solely on traditional banking institutions (Treiblmaier & Beck, 2021).

4.2 Digital Literacy and Workforce Skills Gap

Another major challenge hindering digital transformation in agro-food SMEs is the lack of digital literacy and technical expertise among business owners and employees (Zainal et al., 2022). Many agro-food SMEs are run by individuals with limited experience in using digital tools, making it difficult to adopt and integrate advanced technologies into their operations (Rahim et al., 2022). The absence of adequate training programs further exacerbates this issue, leading to resistance to change and skepticism regarding the benefits of digital adoption (Sharma et al., 2022).

Capacity-building initiatives, vocational training, and industry-led digital upskilling programs are critical for overcoming this barrier (Lal et al., 2022). Governments, universities, and industry associations should collaborate to offer digital training workshops tailored to agro-food businesses (Chandran et al., 2023). Additionally, integrating digital education into agricultural and business curricula can equip future entrepreneurs with the necessary skills to leverage digital tools effectively (He et al., 2021).

4.3 Infrastructure Limitations and Internet Connectivity Issues

Digital transformation in agro-food SMEs is heavily dependent on reliable digital infrastructure, including internet connectivity, cloud computing services, and smart agricultural technologies (Das et al., 2022). However, in Malaysia, many rural areas where agro-food SMEs operate suffer from inadequate digital infrastructure, making it difficult for businesses to implement and sustain digital solutions (Nordin et al., 2021). Limited access to high-speed internet and affordable data services restricts SMEs from utilizing online marketplaces, supply chain tracking systems, and digital payment solutions (Ali & Hossain, 2023).

To bridge the digital divide, policymakers must invest in expanding broadband coverage and improving internet accessibility in rural agricultural regions (Dabbous & Tarhini, 2021). Incentives for private telecommunication companies to extend digital services to underserved areas can facilitate digital adoption among agro-food SMEs (Rahim et al., 2022). Additionally, deploying community-based digital hubs equipped with shared resources, training facilities, and internet access points can provide SMEs with essential technological support (Tian, 2017).

4.4 Cybersecurity Risks and Data Protection Challenges

With increasing reliance on digital platforms and cloud-based services, agro-food SMEs are becoming more vulnerable to cybersecurity threats such as hacking, data breaches, and digital fraud (Zainal et al., 2022). Many SME owners lack awareness of cybersecurity best practices, making them susceptible to online scams, ransomware attacks, and identity theft (Ali & Hossain, 2023). The absence of robust data protection policies and cybersecurity frameworks further exposes SMEs to financial losses and reputational damage (Santos et al., 2023).

To mitigate cybersecurity risks, SMEs must adopt strong security protocols, including encrypted data storage, multi-factor authentication, and regular software updates (Treiblmaier & Beck, 2021). Governments and industry regulators should introduce mandatory cybersecurity training for SMEs and provide financial support for implementing cybersecurity solutions (Dabbous & Tarhini, 2021). Additionally, collaboration with cybersecurity experts and tech firms can help SMEs develop customized security strategies that align with their business needs (Das et al., 2022).

4.5 Regulatory Barriers and Compliance Issues

The regulatory landscape governing digital transformation in the agro-food sector presents another critical challenge for SMEs (Nordin et al., 2021). Compliance with data protection laws, food safety standards, and e-commerce regulations often requires significant time and resources, which many SMEs find burdensome (Rahim et al., 2022). Furthermore, the lack of clear guidelines and regulatory support for emerging technologies such as blockchain and AI in agriculture creates uncertainty among business owners (Chandran et al., 2023).

Governments must simplify regulatory procedures and offer SMEs guidance on compliance with digitalization policies (Dabbous & Tarhini, 2021). The introduction of SME-friendly digital governance frameworks can reduce bureaucratic obstacles and encourage wider technology adoption (He et al., 2021). Additionally, tax incentives and regulatory exemptions for early adopters of digital technologies can accelerate digital transformation in the agro-food sector (Das et al., 2022).

4.6 Addressing Socio-Cultural Resistance to Change

Many agro-food SMEs in Malaysia operate within traditional business models, and resistance to digital transformation remains a significant cultural barrier (Tian, 2017). Some business owners perceive digital technologies as complex, expensive, and unnecessary, leading to reluctance in adopting modern solutions (He et al., 2021). Fear of job displacement among employees and concerns about technological disruptions further contribute to resistance to change (Chandran et al., 2023).

To foster a positive digital adoption mindset, targeted awareness campaigns highlighting the tangible benefits of digital transformation, such as cost savings and efficiency improvements, should be implemented (Das et al., 2022). Government and industry stakeholders can also establish mentorship

programs where successful digital adopters share their experiences with hesitant SMEs (Ali & Hossain, 2023). Additionally, incorporating digital adoption incentives, such as financial rewards for early adopters, can help drive acceptance and integration of technology within the sector (Nordin et al., 2021).

By addressing these key issues, agro-food SMEs in Malaysia can unlock the full potential of digital transformation. Financial support mechanisms, digital literacy programs, improved infrastructure, robust cybersecurity measures, regulatory simplifications, and socio-cultural adaptation strategies are essential in fostering a digitally resilient agro-food sector. Policymakers, industry leaders, and SMEs must collaborate to create an enabling environment that supports sustainable digital adoption and long-term sectoral growth. Future research should focus on assessing the impact of targeted interventions on SME performance, exploring innovative financing models, and developing digital inclusion strategies tailored to the unique needs of the agro-food industry.

5. RECOMMENDATIONS

To successfully implement digital transformation in agro-food SMEs in Malaysia, a multifaceted approach is necessary. The challenges identified in previous sections highlight financial constraints, inadequate infrastructure, digital illiteracy, cybersecurity risks, regulatory issues, and socio-cultural resistance. Addressing these barriers requires a combination of financial support, capacity-building initiatives, technological infrastructure enhancement, cybersecurity awareness, regulatory simplifications, and targeted incentives to drive digital adoption. The following recommendations aim to create an enabling environment for agro-food SMEs to leverage digital technologies effectively and enhance their competitiveness.

5.1 Enhancing Financial Support Mechanisms

Financial constraints remain one of the most significant challenges preventing agro-food SMEs from adopting digital transformation (Lal et al., 2022). Addressing this issue requires increased access to financial resources, including targeted subsidies, low-interest loans, and government grants for SMEs willing to invest in digital tools and platforms (Nordin et al., 2021). Public-private partnerships should be strengthened to provide cost-effective digital solutions, reducing the capital expenditure required for technology adoption (Dabbous & Tarhini, 2021). Moreover, innovative financing models, such as digital crowdfunding platforms and microfinance schemes, should be promoted to enable SMEs to secure investment without relying solely on traditional banking institutions (Rahim et al., 2022).

Government agencies and financial institutions should design specific funding programs that cater to the unique needs of agro-food SMEs, considering the seasonality of agricultural businesses and the varying cash flow cycles (Chandran et al., 2023). Offering financial incentives such as tax breaks or accelerated depreciation on digital investments can further encourage SMEs to embrace technological transformation (Ali & Hossain, 2023). Additionally, financial literacy programs should be introduced to educate SME owners on effective budgeting and resource allocation for digital adoption (Das et al., 2022).

5.2 Improving Digital Literacy and Workforce Training

A significant barrier to digital adoption among agro-food SMEs is the lack of digital literacy and technical expertise (Zainal et al., 2022). Addressing this issue requires structured training programs focused on digital skills development. Government agencies, universities, and industry associations should collaborate to offer digital upskilling workshops and certification programs that equip SMEs with essential

competencies in e-commerce, data analytics, cloud computing, and automation technologies (Sharma et al., 2022).

Integrating digital education into the national curriculum for agricultural and business studies can help prepare future entrepreneurs with the necessary knowledge to leverage digital tools effectively (He et al., 2021). Furthermore, mentorship programs connecting experienced digital adopters with SMEs struggling with digital integration can accelerate knowledge transfer and reduce resistance to change (Sulaiman et al., 2022). By providing accessible and affordable digital training, SMEs will be better positioned to harness technology for operational efficiency and market expansion (Rahman et al., 2022).

5.3 Expanding Digital Infrastructure in Rural Areas

Many agro-food SMEs operate in rural regions where digital infrastructure is inadequate (Kumar et al., 2023). Limited broadband connectivity, unreliable power supply, and lack of access to digital service providers significantly hinder technology adoption (Lal et al., 2022). To address this, policymakers must invest in expanding broadband coverage and improving mobile network accessibility in underserved areas (Dabbous & Tarhini, 2021). Incentives for private telecommunication companies to extend digital services to rural locations should be introduced (Chandran et al., 2023).

Establishing digital service hubs in key agricultural regions can provide SMEs with access to shared resources, training facilities, and technical support (Rahim et al., 2022). These hubs can serve as innovation centers where SMEs can experiment with digital technologies before making full-scale investments (Ali & Hossain, 2023). Additionally, initiatives such as community Wi-Fi projects and satellite-based internet services should be explored to ensure comprehensive digital connectivity for rural agro-food enterprises (Tian, 2017).

5.4 Strengthening Cybersecurity Measures

The increasing reliance on digital platforms exposes SMEs to cybersecurity threats, including data breaches, hacking, and fraud (Zainal et al., 2022). Many SMEs lack the expertise and financial resources to implement robust cybersecurity measures, making them vulnerable to cyberattacks (Santos et al., 2023). To mitigate these risks, SMEs should be encouraged to adopt best practices in cybersecurity, such as multi-factor authentication, encrypted data storage, and regular security audits (Dabbous & Tarhini, 2021).

Government-led initiatives should provide SMEs with financial assistance for cybersecurity investments and facilitate training programs to raise awareness about digital security (Ali & Hossain, 2023). Additionally, developing standardized cybersecurity frameworks for agro-food businesses can ensure compliance with data protection regulations and build trust in digital platforms (Rahim et al., 2022). Collaboration with cybersecurity firms to provide affordable security solutions tailored for SMEs can further enhance digital safety (Das et al., 2022).

5.5 Simplifying Regulatory Frameworks

Regulatory complexity and compliance burdens often deter SMEs from adopting digital technologies (Nordin et al., 2021). Many small businesses struggle to navigate regulations related to digital payments, e-commerce policies, and data protection laws (Rahim et al., 2022). To facilitate digital transformation, the government should simplify regulatory procedures, offering clear guidelines tailored for SMEs (Chandran et al., 2023).

Introducing SME-friendly regulatory policies that encourage innovation while ensuring compliance can enhance confidence in digital adoption (Dabbous & Tarhini, 2021). Additionally, tax incentives, grants, and legal advisory services should be made available to SMEs to help them understand and implement regulatory requirements efficiently (Ali & Hossain, 2023). Reducing bureaucratic red tape and streamlining approval processes for digital projects can significantly accelerate adoption rates among agro-food SMEs (Sulaiman et al., 2022).

5.6 Encouraging Digital Market Participation

Many agro-food SMEs face challenges in accessing digital marketplaces due to high platform fees, competition from large agribusinesses, and limited knowledge of digital marketing (Ismail et al., 2022). To address this, government agencies and industry stakeholders should facilitate SME participation in digital markets through training programs on e-commerce optimization, online branding, and digital customer engagement (He et al., 2021).

Subsidizing initial setup costs for SMEs on major e-commerce platforms can help small businesses establish an online presence without financial strain (Rahim et al., 2022). Additionally, collaborations with established online retailers can provide SMEs with exposure to wider consumer bases, enhancing their competitiveness (Dabbous & Tarhini, 2021). Strengthening logistical support, including warehousing and last-mile delivery services, can further improve SME access to digital marketplaces (Chandran et al., 2023).

5.7 Promoting Cultural and Behavioral Change

Cultural resistance to digital transformation is prevalent among agro-food SMEs, with many business owners perceiving technology adoption as complex and unnecessary (Tian, 2017). To overcome this, awareness campaigns highlighting the tangible benefits of digitalization, such as cost savings and increased efficiency, should be implemented (He et al., 2021). Government and industry stakeholders can establish mentorship programs where successful digital adopters share their experiences with hesitant SMEs (Ali & Hossain, 2023).

Financial incentives, including grants or performance-based rewards, should be introduced to encourage early adoption of digital solutions (Nordin et al., 2021). By fostering a digital adoption culture, agro-food SMEs can develop the confidence and capability to integrate technology into their operations effectively (Rahman et al., 2022).

By implementing these recommendations, Malaysia's agro-food SMEs can harness the full potential of digital transformation, leading to enhanced productivity, market expansion, and long-term sustainability. Future research should assess the impact of these interventions and explore innovative financing models, digital inclusion strategies, and policy refinements to further support digital adoption in the agro-food sector.

6. CONCLUSION

The digital transformation of agro-food SMEs in Malaysia presents a crucial step toward ensuring long-term sustainability, efficiency, and market competitiveness. Digital technologies such as artificial intelligence (AI), blockchain, the Internet of Things (IoT), and big data analytics offer immense benefits, including enhanced productivity, optimized supply chain management, and improved access to markets through e-commerce platforms. Despite these advantages, the adoption of digital technologies among

agro-food SMEs remains low due to financial constraints, limited digital literacy, inadequate infrastructure, cybersecurity risks, and regulatory complexities.

This study highlights that overcoming these barriers requires a multi-dimensional strategy involving financial support, targeted digital literacy programs, enhanced infrastructure, and regulatory improvements. Government policies, such as the National Agro-Food Policy and the Malaysia Digital Economy Blueprint, provide critical support mechanisms for SMEs. However, their effectiveness depends on the accessibility of funding, training, and infrastructure development, particularly in rural areas where digital adoption lags behind. Additionally, stronger public-private partnerships can play a crucial role in facilitating access to digital tools, reducing implementation costs, and providing technical support.
A key finding of this study is that resistance to change among SME owners remains a significant hurdle. Many businesses perceive digital transformation as complex, costly, and uncertain in its return on investment. Addressing these concerns requires structured awareness campaigns, mentorship programs, and financial incentives to encourage early adoption. Furthermore, cybersecurity risks must be mitigated through improved digital security frameworks, training, and financial assistance for SMEs to implement robust data protection measures.

Future research should focus on evaluating the long-term impacts of digital adoption on SME performance, identifying sector-specific digital solutions, and exploring innovative financing models for digital transformation. Additionally, a more localized approach to policy implementation, tailored to the needs of SMEs in different regions, could further enhance adoption rates. By addressing these challenges and fostering an ecosystem that supports digital transformation, agro-food SMEs in Malaysia can achieve greater resilience, operational efficiency, and competitiveness in the global economy. The integration of digital technologies will not only strengthen individual businesses but also contribute to the broader sustainability and growth of Malaysia's agro-food sector.

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