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Digital Transformation and Business Value Creation through Smart Patchouli Oil Distillation

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ABSTRACT

Digital transformation is increasingly important for improving the competitiveness and sustainability of agro-industrial enterprises, particularly in essential oil production where conventional distillation remains constrained by energy consumption, process variability, limited monitoring, and inconsistent product quality. This study examines the potential of Aroma Smart Distiller as a digital transformation innovation for creating business value in patchouli oil production. The system integrates precision steam distillation, Internet of Things (IoT), edge computing, artificial intelligence (AI), adaptive process control, and solar hybrid energy into an integrated smart production platform. An applied research and experimental development approach is used to evaluate operational efficiency, energy consumption, productivity, product quality, and commercialization potential. The proposed system targets a patchouli oil yield of 2.8–3.2%, a 20–30% increase in productivity, and a 30–40% reduction in energy consumption compared with conventional distillation. The integration of real-time monitoring and AI-based optimization also provides production data that can support managerial decision-making, quality control, energy management, and continuous process improvement. From a business perspective, the technology creates value through cost efficiency, productivity enhancement, quality differentiation, sustainability, and access to premium and export markets. The commercialization model further indicates opportunities through equipment sales, intellectual property, licensing, and technology scale-up. The study concludes that smart distillation can function not only as a production technology but also as a strategic digital transformation mechanism for creating sustainable business value and strengthening the competitiveness of small and medium-sized enterprises in the essential oil industry.

Keywords: Digital Transformation; Business Value Creation; Smart Distillation; Patchouli Oil; Internet of Things; Artificial Intelligence; Sustainable Business; Business Model Innovation

Field: Business and Management; Digital Transformation; Business Model Innovation; Technology Management; Sustainable Business; Agro-industrial Management

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SDGs: Affordable and Clean Energy (7); Decent Work and Economic Growth (8); Industry, Innovation and Infrastructure (9); Responsible Consumption and Production (12); Climate Action (13)

INTRODUCTION

The essential oil industry plays an important role in supporting rural economies and small and medium-sized enterprises, particularly through the processing of agricultural commodities such as patchouli. However, the competitiveness of patchouli oil production remains constrained by conventional distillation practices that are highly dependent on manual operation, fossil-fuel-based energy, and limited process monitoring. Conventional patchouli oil distillation is associated with relatively low oil yield, high energy consumption, and inconsistent product quality. The proposal identifies conventional yield at approximately 1.8–2.2%, energy consumption at around 0.9–1.1 liters of diesel per kilogram of raw material, and patchouli alcohol content at approximately 28–34%, which may limit access to premium export markets.

These operational limitations are not merely technical problems but also represent significant business challenges. High energy consumption increases production costs, while inconsistent quality creates uncertainty in pricing, buyer confidence, and market access (Lubaba et al., 2025). Limited automation also increases dependence on experienced operators and reduces the ability of small-scale producers to make production decisions based on real-time information. From a business perspective, these conditions can reduce productivity, operational efficiency, profitability, and the capacity of small and medium-sized essential oil enterprises to compete in premium and international markets. Therefore, digital transformation in the production process needs to be understood not only as the adoption of digital technologies but also as a mechanism for creating measurable business value (Suhardjo et al., 2023).

Digital transformation provides an opportunity to restructure traditional production processes through the integration of Internet of Things (IoT), artificial intelligence (AI), real-time data analytics (Susanti et al., 2024), and renewable energy technologies (Jiao et al., 2025). In the context of patchouli oil production, these technologies can transform distillation from a largely manual process into a data-driven production system. The proposed Aroma Smart Distiller integrates precision distillation, industrial sensors, edge computing, IoT connectivity, AI-based process optimization, and solar hybrid energy within a single production system. The technology enables real-time monitoring of temperature, pressure, steam flow, water level, and energy consumption while supporting adaptive process control and data logging. Consequently, digital technology becomes an operational resource that can potentially influence production efficiency and ultimately contribute to business value creation.

The business value of such digital transformation can emerge through several interconnected mechanisms (Kraus et al., 2022). First, automated monitoring and AI-based process control can improve production consistency and potentially increase yield and productivity. Second, the integration of solar hybrid energy can reduce dependence on fossil fuels and lower energy costs. The proposed system targets a 30–40% reduction in energy consumption compared with conventional fossil-fuel-based distillation, while productivity is expected to increase by approximately 20–30%. Third, digital dashboards and historical production data can support data-driven managerial decision-making, transforming the distillation machine from a production asset into an integrated production management platform.

Furthermore, digital transformation can create strategic business value by improving product quality and enabling producers to pursue higher-value market segments (Liu & Gu, 2026). More consistent distillation conditions are expected to improve the stability of patchouli oil composition, including patchouli alcohol content, thereby strengthening buyer confidence and the competitiveness of Indonesian essential oil products in premium markets. At the organizational level, the adoption of smart distillation can therefore connect operational efficiency with value creation through cost reduction, quality improvement, productivity enhancement, sustainability positioning, and market expansion.

The sustainability dimension further strengthens the business relevance of smart distillation (Nair et al., 2026). The combination of renewable energy, process efficiency, and AI-based optimization has the potential to reduce energy waste and carbon emissions while supporting green production practices. The proposed technology is therefore positioned not only as a production innovation but also as a mechanism for supporting environmental sustainability and improving the market positioning of essential oil enterprises that increasingly need to respond to green production requirements. This integration between digital transformation, operational performance (Renaldo et al., 2022), sustainability, and market opportunity provides an important perspective for examining technology adoption from a business rather than purely engineering standpoint.

The commercialization potential of the technology further demonstrates the relationship between digital transformation and business value creation (Cheng et al., 2026). The proposed Aroma Smart Distiller has an estimated production cost of approximately IDR 65 million per unit and a targeted selling price of IDR 95 million, creating an estimated margin of IDR 30 million per unit. An initial adoption of 20 units is projected to generate approximately IDR 1.9 billion in revenue, with a projected break-even period of 18–20 months. The proposal also estimates a potential national market of approximately 100 units, equivalent to around IDR 9.5 billion in market value. These figures indicate that smart distillation can be examined as a business model and commercialization opportunity rather than simply as a technological upgrade.

Despite the increasing relevance of digital technologies in production, there remains a need to understand how the integration of IoT, AI, renewable energy, and smart manufacturing technologies translates into business value within small and medium-scale essential oil production (Maretto et al., 2023). Much of the technology-oriented perspective focuses on technical performance, whereas the business perspective requires consideration of how technological capabilities contribute to operational efficiency (Fransisca et al., 2025), cost reduction, product quality, sustainability, competitiveness, and commercialization. This study therefore positions digital transformation as a strategic mechanism for business value creation in the patchouli oil industry.

Accordingly, this study aims to examine how digital transformation through smart patchouli oil distillation can create business value by integrating technological capabilities with operational and strategic business outcomes. The study focuses on the relationship between smart production technology, operational efficiency, energy efficiency, product quality, sustainability, and business competitiveness. By connecting digital transformation with business value creation, this study seeks to contribute to the emerging discussion on how Industry 4.0 technologies can generate tangible economic and strategic benefits for small and medium-sized agro-industrial enterprises.

LITERATURE REVIEW

Digital Transformation in Agro-Industrial Enterprises

Digital transformation refers to the integration of digital technologies into organizational processes to improve operational capabilities, decision-making, and business performance (Kraus et al., 2022). In agro-industrial enterprises, digital transformation is particularly relevant because production processes are often characterized by variability in raw materials, dependence on operator experience, and limitations in process monitoring. The adoption of digital technologies can enable organizations to move from experience-based management toward data-driven production and decision-making. Previous research cited in the proposed technology development demonstrates that digital culture and technology adoption can contribute to improvements in firm performance, indicating that digital transformation should be considered not merely as technological adoption but as an organizational and business transformation process.

In the context of essential oil production, digital transformation can be applied directly to the production process through sensors, automated control systems, data acquisition, and digital dashboards. The Aroma Smart Distiller adopts this approach by integrating industrial sensors, edge computing, IoT connectivity, and AI into the distillation process. Such integration allows production parameters to be monitored and controlled continuously while historical data can be used to support managerial decisions. The technology therefore creates an opportunity to connect production-level digitalization with broader business performance, particularly through productivity improvement, cost reduction, quality consistency, and better utilization of production resources.

IoT Enabled Smart Manufacturing and Business Performance

The Internet of Things (IoT) enables physical production equipment to generate, transmit, and process operational data (Soori et al., 2023). In smart manufacturing, IoT can improve visibility over production activities and support real-time monitoring, process control, and performance evaluation. Previous work included in the proposal demonstrates the application of IoT-based systems for agricultural and livestock management, including IoT-enabled weighing devices and IoT-driven smart farming solutions. These studies indicate the potential of IoT to connect physical production activities with digital information systems and improve management capabilities.

The relevance of IoT becomes stronger when it is integrated with production equipment rather than used only as a monitoring tool. Aroma Smart Distiller incorporates temperature, pressure, steam flow, water level, and power sensors connected to an edge IoT controller. The resulting data are processed to support real-time monitoring, automated control, data logging, and cloud-based analytics when connectivity is available. This architecture allows the production system to function under both online and offline conditions through a store-and-forward mechanism, which is particularly relevant for production locations where internet infrastructure may be limited.

Artificial Intelligence and Data Driven Process Optimization

Artificial intelligence provides an additional capability by transforming production data into predictive and optimization functions (J. Wang et al., 2026). While IoT primarily enables data acquisition and connectivity, AI can analyze process relationships and support decisions concerning optimal production parameters. The proposal identifies AI as a mechanism for optimizing temperature, pressure, and energy allocation with the objective of maximizing oil yield while minimizing energy consumption. The use of AI at the edge is particularly important because process optimization can continue without continuous dependence on cloud connectivity.

The combination of IoT and AI consequently creates a transition from passive digital monitoring toward intelligent production management. In Aroma Smart Distiller, the adaptive PID control system and AI optimization module are designed to maintain appropriate distillation conditions and predict yield. This capability is expected to reduce process variability and improve the consistency of patchouli oil quality. From a business perspective, the value of AI is therefore not limited to technical optimization but can be translated into higher productivity, lower operational costs, reduced dependence on highly experienced operators, and improved production planning.

Renewable Energy and Sustainable Business Value

Energy consumption represents an important component of production cost in essential oil distillation (Ait Amer Meziane et al., 2020). Conventional distillation processes may depend heavily on fossil fuels, creating exposure to energy price fluctuations while also generating environmental impacts. The integration of renewable energy into production systems can therefore provide both environmental and economic benefits. Aroma Smart Distiller addresses this issue through a solar hybrid energy architecture consisting of solar panels, MPPT controllers, $LiFePO_4$ batteries, hybrid inverters, thermal storage, and backup heating systems.

The combination of renewable energy and intelligent process control provides a broader basis for sustainable business value creation. The proposed system targets a 30–40% reduction in energy consumption compared with conventional fossil-fuel-based distillation. Lower energy consumption can reduce production costs and improve cost stability, particularly for enterprises operating in areas with limited energy infrastructure. At the same time, renewable energy utilization and process optimization can reduce energy waste and carbon emissions, strengthen the sustainability positioning of the enterprise and potentially improve access to markets that increasingly emphasize green production.

Business Value Creation through Smart Production Technology

Business value creation describes the process through which organizational resources and capabilities are transformed into economic and strategic benefits (Climent & Haftor, 2021). In the context of smart manufacturing, technology creates business value when its implementation contributes to measurable improvements in productivity, efficiency, quality, cost management, customer value, or market competitiveness. Therefore, digital transformation should not be evaluated solely based on technological sophistication but also according to its contribution to business outcomes.

The Aroma Smart Distiller provides several potential pathways for business value creation. Automated process control can improve productivity and yield, while energy optimization can reduce operating costs. Consistent product quality can strengthen buyer confidence and facilitate entry into premium and export markets. Digital dashboards can provide historical and real-time information for managerial decision-making, transforming the production machine into a broader production management platform. The proposal estimates potential productivity improvements of 20–30%, while improved process control is expected to reduce variability and increase consistency of oil production.

Business Model Innovation and Commercialization

Technology-driven business model innovation occurs when technological capabilities enable organizations to develop new ways of creating, delivering, and capturing value (Ancillai et al., 2023). For small and medium-sized agro-industrial enterprises, smart production technology can potentially change the business model from selling commodities based primarily on production volume toward competing through quality, efficiency, sustainability, and technological differentiation. In this context, Aroma Smart Distiller represents more than a production machine because its modular architecture supports integration with existing production systems and creates opportunities for technology licensing, scale-up, and replication across other essential oil commodities.

The commercialization strategy described in the proposal further reinforces the business model perspective. The technology has an estimated production cost of approximately IDR 65 million per unit and a targeted selling price of IDR 95 million, generating an estimated margin of IDR 30 million per unit. An initial adoption target of 20 units is projected to generate approximately IDR 1.9 billion in revenue, while the proposed national market opportunity is approximately 100 units. The commercialization roadmap also includes intellectual property protection, certification, industrial licensing, and scale-up production, demonstrating that the technology is intended to generate value not only through improved production but also through a sustainable commercialization model.

Research Gap

The literature and prior research underlying the proposed technology demonstrate the increasing role of IoT (Sevak & George, 2024), AI (J. Wang et al., 2026), digital platforms, and smart technologies (Adi et al., 2026) in improving organizational and production capabilities. However, the available references in the proposal primarily address digital transformation, IoT applications, AI systems, and smart agricultural management separately. A specific research gap remains in explaining how the simultaneous integration of IoT, edge AI, renewable energy, and smart process control in essential oil distillation can translate into business value for small and medium-sized agro-industrial enterprises.

Therefore, this study positions Aroma Smart Distiller within a business-oriented digital transformation framework. Rather than focusing exclusively on machine performance, the study examines how smart distillation technology can contribute to operational efficiency, energy cost reduction, product quality, sustainability, productivity, competitiveness, and commercialization. This perspective provides the conceptual foundation for investigating the title Digital Transformation and Business Value Creation through Smart Patchouli Oil Distillation, with digital technology functioning as a strategic capability for transforming production resources into economic and competitive value.

METHODOLOGY

Research Design

This study employs an applied research and experimental development design to examine how digital transformation through the Aroma Smart Distiller contributes to business value creation in patchouli oil production (Katekar et al., 2023). The research focuses on the integration of precision steam distillation, Internet of Things (IoT), edge computing, artificial intelligence (AI), and solar hybrid energy as an integrated production system. The research follows the technology development roadmap from TKT 6 toward TKT 9, covering system integration, laboratory validation, industrial pilot testing, industrial validation, and commercialization readiness. The approach allows technical performance and business implications to be evaluated simultaneously rather than treating the technology solely as an engineering innovation.

Research Setting and Technology Object

The research object is the Aroma Smart Distiller; a smart patchouli oil distillation system designed for small and medium-sized essential oil enterprises. The system combines a food-grade stainless-steel precision distillation reactor, high-efficiency condenser, solar hybrid energy system, industrial sensors, low-power fanless edge IoT controller, adaptive PID control, AI-based optimization, and a digital dashboard. The system monitors temperature, pressure, steam flow, water level, and energy consumption to support real-time and offline process management.

Research Stages

The research is conducted through five sequential stages. The first stage involves technical integration and design, including integration of the precision distillation reactor, IoT sensors, firmware, adaptive PID control, and solar hybrid energy system. The second stage involves laboratory validation through sensor calibration and measurement of yield, energy consumption, and product quality. The third stage consists of industrial pilot testing and AI optimization, including field implementation for at least three months, dashboard development, store-and-forward implementation, SOP development, and intellectual property preparation. The fourth stage focuses on industrial validation, reliability testing, design iteration for manufacturing, and certification preparation. The final stage addresses initial production, intellectual property finalization, licensing, and scale-up.

Data Collection

Data are collected from both technical and business-related dimensions. Technical data include reactor temperature, pressure, steam flow, water level, energy consumption, distillation duration, oil yield, and product quality. Product quality is assessed through chemical analysis, including GC-MS or GC-FID, to evaluate the composition and quality of patchouli oil. Operational data are obtained through the IoT sensors and edge controller, while historical production data are stored through the data-logging and store-and-forward mechanisms. Field data are collected during pilot implementation with the industrial partner to evaluate system stability and practical operational performance.

Measurement of Business Value

Business value is evaluated through several indicators that connect technological performance with organizational outcomes (Nguyen, 2026). The main indicators include production yield, productivity, energy consumption, energy cost, product quality consistency, operational efficiency, and potential market competitiveness. Changes in productivity and energy efficiency are compared with conventional distillation practices as the baseline. The proposed technology targets a yield of approximately 2.8–3.2%, a 30–40% reduction in energy consumption, and a 20–30% increase in productivity compared with conventional processes. These indicators are subsequently interpreted in terms of production cost reduction, value creation, and competitiveness rather than being treated only as technical performance measures.

Comparative Analysis

A comparative analysis is conducted between conventional local distillation, imported distillation equipment, and the proposed Aroma Smart Distiller. The comparison covers yield, energy consumption, process consistency, control mechanisms, monitoring capability, operating cost, and machine investment. This approach is intended to determine whether digital transformation generates superior operational and economic value relative to existing alternatives. The proposal identifies conventional local distillation as having a yield of approximately 1.8–2.2%, while imported equipment is estimated at 2.2–2.6%; the proposed system targets 2.8–3.2%.

Business Model and Commercialization Analysis

The business implications of the technology are evaluated using a commercialization and business model perspective. The analysis considers production cost, selling price, estimated unit margin, potential adoption, break-even period, market potential, intellectual property, licensing, and scale-up opportunities. The proposed business model positions Aroma Smart Distiller as a technology product that can be commercialized through industrial adoption and licensing. The proposal estimates a production cost of approximately IDR 65 million and a targeted selling price of IDR 95 million per unit, with an initial target of 20 units and potential national adoption of approximately 100 units.

Data Analysis

The collected data are analyzed using descriptive and comparative analysis to identify changes in technical performance and business outcomes before and after implementation (Fattah et al., 2025). Performance indicators are calculated from production and operational records, while percentage changes are used to evaluate improvements in yield, productivity, and energy efficiency. Economic analysis is subsequently used to translate operational improvements into potential cost savings, margins, revenue opportunities, and investment feasibility (Setyawan et al., 2025). The analysis is complemented by qualitative evaluation from operators and the industrial partner concerning ease of operation, reliability, data availability, and perceived business benefits. This approach reflects the proposal's emphasis on co-design, co-development, industrial validation, and co-commercialization between the university research team and industry partner.

Validity and Reliability

Technical validity is established through laboratory testing, sensor calibration, baseline performance measurement, pilot testing, and industrial reliability testing (Borges & Oliveira, 2026). Product quality is validated through laboratory analysis, while operational reliability is evaluated during field implementation. The research also applies risk mitigation through modular system design, sensor redundancy, hybrid energy backup, AI optimization based on pilot data, store-and-forward functionality, operator training, and digital SOPs (Panjaitan et al., 2025). Industrial validation and certification preparation are conducted during the later stages to strengthen the reliability and readiness of the technology for commercialization.

Research Collaboration

The research is conducted collaboratively between the university research team and the industrial partner. The university team is responsible for technology development, laboratory testing, AI and IoT development, quality analysis, intellectual property, and technology and business model development, while the industrial partner provides the field-testing environment, patchouli raw materials, existing equipment, operators, and support for pilot and reliability testing. This collaborative arrangement ensures that the assessment of business value reflects actual industrial conditions and not only laboratory performance.

RESULTS AND DISCUSSION

Result

Digital Transformation of Patchouli Oil Distillation

The development of Aroma Smart Distiller demonstrates a transition from conventional manual distillation toward an integrated digital production system. The proposed system combines precision steam distillation, industrial IoT sensors, edge computing, AI-based process optimization, and solar hybrid energy in a single production architecture. Temperature, pressure, steam flow, water level, and energy consumption are monitored continuously, while the edge controller enables process control and data logging. The store-and-forward mechanism also allows the system to continue collecting and processing operational data when internet connectivity is unavailable.

This transformation is important from a business perspective because digitalization changes the role of the distillation machine from a conventional production asset into a data-driven production management system (D. Wang & Shao, 2024). The availability of real-time and historical production data provides managers with greater visibility over production performance, energy utilization, and quality. The dashboard further enables production information to be used for decision-making and performance evaluation. Thus, digital transformation creates value not only through automation but also through improved information availability and managerial control.

Improvement in Operational Efficiency and Productivity

The proposed technology is designed to address the low efficiency of conventional patchouli oil distillation. Existing conventional processes are reported to produce yields of approximately 1.8–2.2%, while the Aroma Smart Distiller targets a yield of 2.8–3.2%. The system also targets a 20–30% increase in productivity through automated monitoring, precision process control, and optimization of distillation parameters.

From a business perspective, higher yield and productivity have direct implications for value creation (Hall, 2018). Higher output from comparable production resources can increase revenue-generating capacity without requiring proportional increases in labor and operating resources. At the same time, automated control reduces process variability and dependence on operator experience. The proposed system therefore creates operational value through more efficient utilization of production capacity, improved process consistency, and reduced operational complexity.

Energy Efficiency and Cost Reduction

One of the most significant results expected from the technology is improvement in energy efficiency. Aroma Smart Distiller integrates solar panels, batteries, hybrid inverters, thermal storage, and backup heating with AI-based energy optimization. The system is designed to reduce fossil-fuel energy consumption by approximately 30–40% compared with conventional distillation.

This energy reduction has an important business implication because energy represents a recurring production cost (Aduba et al., 2025). Unlike a one-time technological investment, energy savings can generate value throughout the operational life of the equipment. Reduced dependence on fossil fuels can also improve cost stability for producers operating in areas where energy access and prices may fluctuate. Consequently, the solar hybrid system functions simultaneously as a sustainability technology and a cost-management mechanism. The integration of AI further strengthens this benefit by allocating energy according to process requirements rather than relying exclusively on fixed or manual operating conditions.

Product Quality and Market Competitiveness

The results indicate that product quality consistency is a central business outcome of the proposed technology. Conventional patchouli oil distillation is reported to produce patchouli alcohol levels of approximately 28–34%, which may not consistently meet the premium export benchmark identified in the proposal. Aroma Smart Distiller is designed to stabilize temperature and pressure conditions through precision control, thereby improving the consistency of the distillation profile and supporting higher-quality oil production.

Improved quality consistency can create business value through higher buyer confidence and access to premium market segments (Cano et al., 2023). In commodity-based industries, technological capability can therefore become a source of differentiation when it enables producers to deliver more consistent products. The technology is consequently positioned to move producers beyond competition based primarily on production volume toward competition based on quality, efficiency, sustainability, and reliability. This provides a strategic link between process digitalization and market competitiveness.

Integration of IoT and AI as a Source of Business Value

The integration of IoT and AI represents a particularly important result because the technologies perform complementary functions. IoT provides continuous access to operational data, while AI uses these data to support optimization of temperature, pressure, and energy consumption. The proposed architecture incorporates an adaptive PID control system and AI optimization engine, allowing process parameters to be adjusted according to production requirements.

The business significance of this integration lies in the conversion of operational data into actionable information (Champa & Segall, 2026). A conventional machine primarily produces physical output, whereas the smart distiller produces both physical output and digital information. This information can support production planning, quality monitoring, maintenance decisions, energy management, and performance evaluation. The resulting capability strengthens organizational decision-making and provides a foundation for continuous process improvement.

Sustainability as a Component of Business Value

The integration of renewable energy and digital process optimization also produces an environmental dimension of business value. Solar energy reduces reliance on fossil fuels, while AI-based optimization seeks to minimize unnecessary energy consumption. The proposal identifies these characteristics as supporting reductions in carbon emissions and energy waste while strengthening the sustainability positioning of the industrial partner.

Sustainability can therefore function as both an environmental objective and a competitive business resource. Producers that can demonstrate more efficient and environmentally responsible production may strengthen their positioning in markets where buyers increasingly consider production practices alongside product quality. In this sense, Aroma Smart Distiller links operational sustainability with potential market differentiation.

Business Model Innovation and Commercialization Potential

The results also demonstrate that the technology has potential beyond internal operational improvements. Aroma Smart Distiller is designed as a modular system that can be replicated across small and medium-sized essential oil enterprises and potentially adapted for other commodities such as clove, citronella, and nutmeg. The proposed commercialization model combines technology production, intellectual property, licensing, and industrial scale-up.

The economic projection strengthens this business argument. The proposed production cost is approximately IDR 65 million per unit, with a target selling price of IDR 95 million, producing an estimated margin of IDR 30 million per unit. An initial adoption of 20 units is projected to generate approximately IDR 1.9 billion in revenue, while the estimated potential national market of 100 units represents approximately IDR 9.5 billion. The proposal also estimates a break-even period of 18–20 months.

These figures suggest that digital transformation can create value at two interconnected levels. At the user level, the technology creates value through increased productivity, lower energy consumption, improved quality, and better decision-making. At the technology-provider level, it creates value through equipment sales, licensing, intellectual property, and future scale-up. This dual value-creation mechanism is an important characteristic of technology-driven business model innovation.

Industrial Validation and Commercialization Readiness

The development roadmap indicates progressive movement from technical validation toward industrial commercialization. During months 7–12, the technology is planned for field testing of at least three months, AI optimization, sensor calibration, SOP development, and business model formulation. During months 13–18, reliability testing and manufacturing-oriented design iteration are planned, followed by initial production, licensing, and scale-up during months 19–24.

This staged approach is significant because successful digital transformation requires more than a functioning prototype (Buonocore et al., 2024). Industrial adoption depends on reliability, usability, standardization, certification, operator readiness, and commercial feasibility. The proposed collaboration with the industrial partner addresses these dimensions by involving the partner in field testing, specification development, validation, and commercialization. The partner has also expressed an initial adoption commitment for at least 20 units and a planned technology licensing arrangement.

Discussion

The findings and proposed performance indicators demonstrate that Aroma Smart Distiller can be conceptualized as a business-oriented digital transformation innovation, rather than simply an advanced distillation machine (Queiroz et al., 2024). The integration of IoT, AI, renewable energy, and precision process control create interconnected benefits across operational efficiency, energy management, product quality, sustainability, and market competitiveness (Hussein et al., 2025). The technology consequently provides a pathway through which digital capabilities can be transformed into tangible economic and strategic value (Le et al., 2026).

The central contribution of this innovation is therefore the connection between digital transformation and business value creation. IoT generates production visibility, AI converts operational data into optimization, renewable energy reduces energy dependence, precision control improves product consistency, and the resulting improvements support productivity, cost efficiency, market access, and commercialization. This integrated perspective supports the argument that digital transformation in agro-industrial enterprises should be evaluated not only through technological performance but also through its ability to create sustainable and commercially relevant business value.

CONCLUSION

Conclusion

This study concludes that Aroma Smart Distiller represents a digital transformation approach that can connect smart production technology with business value creation in the patchouli oil industry. The integration of IoT, edge computing, AI-based process optimization, precision steam distillation, and solar hybrid energy transforms conventional distillation into a more measurable, controllable, and data-driven production process. The proposed system is designed to improve yield and productivity, reduce energy consumption, strengthen product quality consistency, and support data-driven managerial decision-making.

The business potential of the technology is reflected in its ability to generate value through operational efficiency, energy cost reduction, product differentiation, sustainability, and commercialization. The proposed targets include a 20–30% increase in productivity and a 30–40% reduction in energy consumption, while the targeted selling price and projected market adoption indicate opportunities for technology-based revenue creation. Therefore, Aroma Smart Distiller can be positioned not merely as a technological innovation but as a business model innovation that supports sustainable competitiveness in the essential oil industry.

Implications

The theoretical implication of this study is that digital transformation in agro-industrial enterprises can be viewed as a mechanism for converting technological capabilities into business value. IoT provides production visibility, AI enables process optimization, renewable energy contributes to cost and environmental efficiency, while digital data support managerial decision-making. This extends the discussion of digital transformation beyond technology adoption toward its consequences for productivity, efficiency, quality, sustainability, and competitiveness.

The practical implication is particularly relevant for small and medium-sized essential oil enterprises. Adoption of smart distillation technology can help producers reduce dependence on manual process control, improve energy management, strengthen quality consistency, and generate production data for managerial decisions. The technology also provides opportunities for producers to enter premium and export markets through more consistent product quality. For technology developers and industry partners, the findings support a commercialization strategy based on equipment sales, intellectual property, licensing, and production scale-up.

Limitations

This study has several limitations. First, the reported performance improvements represent proposed technology targets and development indicators rather than fully established results from long-term industrial operation. The proposal is still structured around progressive validation from TKT 6 toward TKT 9, including laboratory testing, pilot implementation, reliability testing, and industrial validation. Second, the economic projections are based on estimated production costs, selling prices, adoption targets, and market potential and therefore may change according to actual manufacturing, operational, market, and commercialization conditions. Third, the study focuses primarily on patchouli oil distillation, meaning that the generalizability of the findings to other essential oil commodities requires further validation.

Recommendations

Future implementation should prioritize systematic industrial validation of the targeted improvements in yield, productivity, energy consumption, and product quality. Laboratory and field data should be collected continuously to compare the Aroma Smart Distiller with conventional distillation under comparable production conditions. Sensor calibration, reliability testing, operator training, and digital SOP implementation should also be strengthened to ensure that technological benefits can be maintained under actual operating conditions.

From a business perspective, commercialization should be supported by continuous evaluation of production costs, customer willingness to adopt, pricing, unit margins, break-even periods, licensing arrangements, and market demand. The proposed collaboration model involving co-design, co-development, and co-commercialization should be maintained so that subsequent product development remains aligned with actual industry requirements.

Future Research

Future research should conduct longitudinal industrial studies to establish the actual relationship between digital transformation and business performance after prolonged adoption of Aroma Smart Distiller. Research should examine whether improvements in yield, energy efficiency, quality consistency, and productivity translate into measurable changes in profitability, return on investment, market access, and competitive advantage.

Further studies could also develop quantitative models linking IoT capability, AI capability, energy efficiency, operational efficiency, business value creation, and firm competitiveness. Comparative research involving multiple essential oil producers would provide stronger evidence regarding the scalability and generalizability of the technology. In addition, the system can be investigated for adaptation to other essential oil commodities, including clove, citronella, and nutmeg, as envisioned in the post-program development roadmap. Finally, future research should investigate the potential of predictive maintenance, advanced AI optimization, carbon accounting, and digital business models to further expand the economic and sustainability value generated by smart distillation technology.

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